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Full Length Article

# Tourism-energy-economy-environment nexus toward sustainable and green development in Malaysia

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ABSTRACT

This study investigated the impact of tourism on Malaysia's energy consumption, economic development, and environmental sustainability. The study employed a time series analysis from 1995 to 2020 using Autoregressive Distributed Lag (ARDL) to assess both short- and long-term dynamics. The estimation suggests that a 1 % increase in tourist arrivals, tourism expenditures, and tourism receipts would result in energy consumption increasing by 0.46 %, 0.47 %, and 0.64 % in the long term, and by 0.30 %, 0.31 %, and 0.51 % in the short term, respectively. Additionally, a 1 % rise in tourist arrivals, tourism expenditures, and tourism receipts would lead to a long-term increase in economic growth of 0.45 %, 0.47 %, and 0.54 %, respectively. In the short term, these increases would be 0.26 %, 0.32 %, and 0.40 %. Furthermore, a 1 % rise in tourist arrivals and tourism expenditures would result in a long-term increase of 0.32 % and 0.26 % in carbon emissions, and a short-term increase of 0.39 % and 0.29 %, respectively. The findings suggest that a 1 % rise in tourism receipts would lead to a reduction of 0.10 % in carbon emissions in the long term and 0.03 % in the short term. The results were validated using alternative cointegration regression methods. The study provides policy recommendations for sustainable tourism.

## 1. Introduction

The tourism sector plays a crucial role in driving global economic growth and progress. Tourists contribute to a nation's GDP growth through employment, taxes, and consumer spending. The tourism industry contributed approximately US$ 9170 billion to the global economy in 2019, accounting for 10.4 % of the worldwide GDP (WTTC, 2024). Approximately 25 % of global job growth between 2014 and 2019 can be attributed to the travel and tourism sector. There were 334 million new jobs created globally in 2019 (WTTC, 2024). Tourism-related businesses, including those in hospitality, accommodation, and catering, generate employment opportunities that address unemployment and promote growth in manufacturing and service sectors. This, in turn, contributes to the economic development of both developed and developing countries, such as Malaysia (Shaliza et al., 2023). Tourism is a significant contributor to Malaysia's overseas revenue and plays a crucial role in the country's overall development. In 2019, Malaysia received approximately 26 million international tourists, which is close to the country's total population. In 2023, the tourism sector in Malaysia accounted for 14.7 % of the nation's GDP. Furthermore, Malaysia's tourism industry contributed to 23 % of total employment in the country (World Bank, 2024; Begum et al., 2025).

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This tourism business employed approximately 1.5 million individuals either directly or indirectly. Malaysia has implemented multiple tourism campaigns to increase tourist arrivals. Malaysia prioritizes the promotion of itself as a leisure and business destination, both domestically and globally. Malaysia aims to promote itself as a preferred international destination for both tourists and business travelers, with the goal of establishing the tourism industry as a significant socio-economic contributor to the country (Musa & Nadarajah, 2023).

An increase in tourist arrivals, both domestic and global, can boost a country's income. However, this also leads to higher energy consumption (Kumail et al., 2023). Dogan and Aslan (2017) identified two significant factors that contribute to the higher consumption of energy: the increased number of hotel stays and the greater use of the public transit system. High energy consumption has significant negative environmental consequences (Raihan et al., 2022, 2023, 2024, 2025). An increase in atmospheric carbon dioxide ($CO_2$) concentration contributes to climate change. Tourism has a direct impact on climate change due to its association with carbon emissions and energy use (Raihan, 2023). The World Tourism Organization (UNWTO) reports that tourism contributes nearly 5 % of global emissions, with transportation accounting for 75 % and lodging facilities for 20 % of these emissions. The framework of economic and transportation activities is shaped by domestic energy consumption, highlighting the interconnection between tourism growth and $CO_2$ emissions. In the past three decades, there has been a significant increase in both the number of tourists visiting Malaysia from other countries and the country's overall energy consumption. This increase has also led to a substantial rise in carbon emissions. In 2018, the transport sector accounted for 36.4 % of Malaysia's total final energy demand, equivalent to 235 million tons of oil. This makes it the largest energy consumer in the country. $CO_2$ accounts for 96 % of greenhouse gas emissions in this particular sector. The transport sector in Malaysia accounted for 28.8 % of total fossil fuel combustion, which is higher than the global average of 24.5 % (Solaymani, 2022). Carbon emissions remain a significant challenge for Malaysia's energy sector (Raihan & Tuspekova, 2022). Malaysia should implement strategic procedures and planning to address issues in the tourism sector. In order for the government of Malaysia to pass laws limiting carbon emissions from the tourism industry, it is crucial to first comprehend the substantial impact of tourism on overall energy consumption.

Policymakers in Malaysia have advocated a path to carbon neutrality as a means to reduce domestic emissions and mitigate global warming. Regrettably, the importance of tourism in achieving carbon neutrality in Malaysia has been overlooked. The stagnation of Malaysia's tourism industry can be attributed to factors such as lack of appealing creativity and innovation, excessive reliance on government initiatives, overdependence on traditional marketing methods, unsustainable physical development, and inadequate destination management in tourism-related agencies. According to Malaysia's National Tourism Policy (2020–2030), there is a need to transform the tourism industry in Malaysia in order to increase its competitiveness and ensure sustainability and resilience. This is important despite the significant income contribution to the country's GDP, and it should be done without causing harm to the environment and domestic economy. Malaysia's tourism industry shows signs of stagnation due to unappealing creativity and innovation, excessive reliance on government initiatives, overdependence on traditional marketing, unsustainable physical development, and inadequate destination management in tourism-related agencies. Therefore, it is necessary to reinvent and transform the industry in order to maintain competitiveness, adopt sustainable practices, and promote responsible consumption. This is particularly important in supporting policies aimed at achieving net zero emissions and decarbonization.

The tourism-energy-economy-environment framework is crucial for study as it provides a comprehensive approach to understanding the interconnections between tourism, energy consumption, economic growth, and environmental sustainability. Tourism is a major driver of economic development, but it also requires significant energy resources, leading to environmental challenges such as carbon emissions and resource depletion. By studying the tourism-energy-economy-environment framework, policymakers, researchers, and businesses can identify sustainable strategies that balance economic benefits with energy efficiency and environmental protection. This integrated perspective helps in mitigating negative impacts, promoting renewable energy use, and ensuring long-term sustainability in the tourism sector while maintaining economic prosperity. Hence, the intricate interplay among energy, economy, emissions, and tourism has attracted considerable attention from scholars.

While many studies have examined the economic and environmental impacts of tourism (Farooq et al., 2024; Naseem, 2021), there is a research gap specifically examining the influence of tourism within the energy-economy-environment framework. Furthermore, the existing literature does not provide a conclusive assessment of the precise environmental impact of tourism. Several studies have found a positive correlation between tourism and carbon emissions (Khanal et al., 2022; Nwaeze et al., 2023). However, other studies have suggested that tourism can help reduce carbon emissions (Ullah et al., 2023; Wei & Lihua, 2023). There is a research gap in the current literature regarding the precise impact of various tourism indicators using econometric methods. Moreover, prior research has focused solely on tourist arrivals as an indicator of tourism (Adebayo et al., 2023; Voumik et al., 2023), neglecting the significance of tourism expenditures and tourism receipts. Thus, there is a research gap in investigating the influences of tourism expenditures and tourism receipts on energy demand, economic growth, and environmental quality. Furthermore, there is a lack of research on the impact of tourism indicators on economic progress, carbon neutrality, and the achievement of sustainable development goals (SDGs).

The objective of this study is to address the research gaps in the current literature by investigating the impact of tourist arrivals, tourism expenditures, and tourism receipts on the economic growth, energy consumption, and carbon emissions of Malaysia. Malaysia's unique economic structure, energy policies, and rich tourism sector make it an interesting case for studying the tourism-energy-economy-environment nexus. As a rapidly developing country with a strong reliance on fossil fuels, an expanding tourism industry, and ambitious sustainability goals, Malaysia provides insights into the dynamic interplay between these factors. Findings from Malaysia's tourism-energy-economy-environment nexus analysis can have broader implications for other emerging economies, particularly those with similar characteristics, such as middle-income ASEAN countries (e.g., Thailand, Indonesia, and the Philippines) and resource-rich developing nations. These countries face comparable challenges in balancing economic growth, environmental sustainability, and energy consumption while leveraging tourism as a key economic driver. The Malaysian experience can offer valuable policy lessons on optimizing tourism's economic benefits while mitigating its environmental impact through sustainable energy practices.

This study contributes to the existing literature on the relationship between tourism, energy, the economy, and the environment in several ways. Firstly, while many studies have examined the economic and environmental impacts of tourism (Farooq et al., 2024; Naseem, 2021), there are limited studies examining the influence of tourism within the energy-economy-environment framework. The present study investigates the influences of different tourism indications on energy demand, economic growth, and environmental quality. Besides, the existing literature does not provide a conclusive assessment of the precise environmental impact of tourism. Several studies have found a positive correlation between tourism and carbon emissions (Khanal et al., 2022; Nwaeze et al., 2023). However, other studies have suggested that tourism can help reduce carbon emissions (Ullah et al., 2023; Wei & Lihua, 2023). The present study contributes to the current literature regarding the precise impact of various tourism indicators using econometric methods. Furthermore, prior research has focused solely on

tourist arrivals as an indicator of tourism (Adebayo et al., 2023; Voumik et al., 2023), neglecting the significance of tourism expenditures and tourism receipts. As per the authors' knowledge, no previous study has examined the impact of various tourism indicators, such as tourist arrivals, tourism expenditures, and tourism receipts, on energy use, economic growth, and environmental sustainability using econometric methods in the context of any country. The present study contributes to the existing literature by investigating the influences of tourism expenditures and tourism receipts within the energy-economy-environment framework. This study is the first to examine the effects of tourist arrivals, tourism expenditures, and tourism receipts on energy use, economic growth, and environmental sustainability in Malaysia. To ensure the accuracy of the study's outcomes the present study employed multiple unit root tests (ADF, DF-GLS, P-P), diagnostic tests, and cointegration models (ARDL, DOLS, FMOLS, CCR). Secondly, while the previous studies only focused on tourism's effect on Malaysia's economy (Puah et al., 2018), the current study examines the sustainability principles of the tourism industry in Malaysia, with a specific emphasis on the environmental, economic, and socio-cultural aspects of tourism development. Besides, this article offers policy recommendations for promoting sustainable tourism in Malaysia. These recommendations aim to generate employment, support local culture and products, and achieve a balanced approach that considers socio-cultural, economic, and environmental factors. By implementing these recommendations, the long-term sustainability of the tourism industry in Malaysia can be ensured. The study's findings would benefit policymakers in Malaysia and other developing countries seeking to leverage tourism for economic growth. Furthermore, the study emphasized the importance of promoting clean energy and financing renewable energy technologies in tourism activities in Malaysia as a significant contribution. This effort aligns with the goal of achieving SDG 7 (sustainable energy). In addition, while the previous studies only focused on investigating the relationship between tourist arrivals and carbon emissions (Azam et al., 2018), the present research highlights the importance of addressing pollution, waste management, and supporting Malaysia's cultural heritage sites to attract more international tourists and achieve sustainable economic growth (SDG 8), sustainable consumption and production (SDG 12), carbon neutrality (SDG 13), and sustainable use of natural resources (SDG 14). However, global tourism is significantly increasing after the COVID-19 pandemic, helping countries recover from economic challenges. A comprehensive study that integrates tourism, energy, economy, and emissions can effectively address the national development aspects of Malaysia. The present study can serve as valuable background material for the formulation of national policies aimed at sustainable tourism, green economy, energy efficiency, emission reduction, carbon neutrality, promoting renewable energy, and achieving Malaysia's commitments under the Paris Agreement. Finally, the analysis of the tourism-energy-economy-environment nexus in Malaysia presents findings that may extend their relevance to other emerging economies, especially those sharing similar traits, including middle-income ASEAN nations as well as resource-abundant developing countries. The experience in Malaysia provides insightful policy lessons on enhancing the economic advantages of tourism while addressing its environmental consequences through sustainable energy approaches.

## 2. Literature review

### 2.1. Tourism and economic growth

The tourism-led growth hypothesis (TLGH) was initially proposed by Balaguer and Cantavella-Jorda (2002) to examine the relationship between tourism and economic growth. The findings indicate that tourism contributes to economic growth. One key principle of this theory is that tourism plays a significant role in GDP growth. Subsequent researchers have contributed to the further development of this theory in different contexts, building upon the groundwork established in this study. Corrie et al. (2013) examined the impact of tourism on Australia's GDP. The research team conducted Granger causality tests and determined that there is a mutual causal relationship between the Australian economy and tourism. Ghartey (2013) conducted a study on the impact of tourism on Jamaica's economy from 1963 to 2008. The results of both the long-run and short-run ARDL analysis indicate a positive relationship between the number of visitors and economic growth. Balsalobre-Lorente and Leitão (2020) conducted further investigations to assess the validity of the TLGH in multiple European Union countries, employing diverse econometric methodologies. The findings indicate that a 1 % increase in tourist numbers leads to a 0.62 % increase in GDP growth. These findings further validate the TLGH for EU member states. Wu et al. (2022) examined the relationship between tourism and economic growth in 11 Asian regions using data spanning from 1995 to 2016. The reliability of the TLGH in Cambodia, China, Macau, Malaysia, and Thailand was assessed using the multivariate wavelet method. Tang and Tan (2018) utilized a panel dataset comprising 167 countries spanning the years 1995–2013. The study provides global evidence supporting the validity of the TLGH. The panel GMM analysis found that a 10 % increase in tourism receipts is associated with a 0.3 % increase in GDP growth. The evidence clearly demonstrates that the tourism industry has a substantial impact on promoting global prosperity.

Perles-Ribes et al. (2017) utilized data spanning from 1957 to 2014, taking into account the impact of the 2008 economic crisis, to apply the TLGH model to Spain. The authors used tourist arrivals and tourism receipts as proxies for measuring tourism. The validity of TLGH was confirmed through cointegration and Granger causality tests. However, the test failed when tourist receipts were used. Ertugrul and Mangir (2015) conducted a study in Turkey using the TLGH and concluded that tourism has a significant impact on GDP growth. The study employed the bounds test method and Granger causality to examine the empirical relationship between tourism and GDP growth during the period from 1998 to 2011. ARDL's long-term estimate suggests that a 1 % increase in tourism leads to a 0.24 % increase in GDP. There is strong evidence indicating that tourism plays a significant role in driving GDP growth. According to Wong et al. (2022), there is a positive correlation between an increase in foreign tourism and economic growth in eastern China. Matzana et al. (2022) confirmed the positive impact of tourism on economic growth in EU countries, supporting the theory of TLGH. Cannonier and Burke (2019) employed panel data spanning three decades to examine the causal relationship between tourism and economic growth, with a specific focus on Caribbean islands. The results showed that tourism has a positive and statistically significant effect on real GDP growth. The study reveals that a 10 % rise in tourism expenditure leads to a boost in economic growth, increasing it from 0.3 % to 1 %. Khan (2020) examined the effects of tourist arrival, tourism growth, and tourism expenditure on Italy's economic growth using annual time series data from 1995 to 2018. The results of the t-statistics and Wald F-test indicate that there is a two-way causal relationship between economic growth and tourism growth, as well as between economic growth and tourist arrivals. Additionally, there is a one-way causal relationship from economic growth to tourism expenditure and from tourism growth to tourism expenditure. However, there is no causal association between tourist arrivals and tourism expenditure. Naseem (2021) examined the impact of tourism on economic growth in Saudi Arabia using annual time series data from 2003 to 2019. The study employed various statistical tests, including basic statistics, correlation coefficients, the unit root test, the Johansen co-integration test, the co-integration regression test, and the Granger causality test, to examine the relationship between tourism and economic growth. The study findings indicate a significant long-term association between economic growth and variables such as tourism receipts, tourism expenditures, and the number of tourist arrivals. Among these variables, the number of tourist arrivals exhibits a particularly strong relationship with economic growth. The empirical results support the notion that tourism

contributes to economic growth in Saudi Arabia.

Nevertheless, the TLGH has been contradicted by multiple studies. The TLGH was examined by Kyophilavong et al. (2018) through an ARDL strategy and the Granger causality test, but no support was found for either. Aslan (2014) examined the relationship between tourism expansion and GDP growth in Mediterranean countries from 1995 to 2010. The study found no evidence to support the TLGH in Malta or Egypt based on panel Granger causality tests. While the majority of studies in the current literature suggest that tourism has a positive impact on economic growth, the conflicting results from some research necessitate a deeper examination of the validity of the TLGH hypothesis, especially in the context of tourism-dependent developing nations such as Malaysia.

### 2.2. Tourism and energy use

In recent times, there has been significant attention given to the correlation between tourism and energy usage. Katircioglu (2014) employed impulse response and variance decomposition techniques to estimate the relationship between tourism and energy consumption. The main factor contributing to the increase in energy consumption was the long-term growth of tourism. Katircioglu et al. (2014) found that a 1 % increase or decrease in tourism is associated with a 0.033 % change in $CO_2$ emissions and a more substantial shift of 0.619 % in energy consumption. This change would have a greater impact than the previous one. The study employed the ARDL and Granger causality tests to analyze a dataset spanning 39 years. The study determined that tourism significantly contributes to the long-term rise in energy consumption. Jebli and Hadhri (2018) used the feedback hypothesis to verify the existence of a short-term Granger causality between the growth of economic sectors in tourist areas and their energy usage. The correlation between the two variables was examined over a five-year period. A single long-term causation path between energy use and international travel was identified by researchers using a vector error correction model (VECM). A bidirectional causation was found to exist based on the results of a short-run Granger causality test. Tang et al. (2016) examined the complex connections and interactions among India's tourism industry, GDP growth, and energy consumption. The data collected for this study spanned from 1971 to 2012. The study employed the bounds testing approach and the Gregory-Hansen test to analyze cointegration, detecting a structural break. The overestimation of energy requirements can be attributed to both economic expansion and the tourist sector. Approximately 9 % of the difference between GDP and tourism can be attributed to energy consumption. The growth in tourism and the economy had a significant impact on the total energy consumption.

Ali et al. (2018) conducted a study on nineteen countries in the Asia Cooperation Dialogue. The study analyzed data collected from 1995 to 2015. A significant correlation was discovered between the utilization of renewable energy and tourism in countries with higher GDP, supporting the notion of a reciprocal relationship between these two sectors. Gokmenoglu and Eren (2020) conducted a comprehensive analysis of 55 years of data spanning from 1960 to 2015 to assess the influence of international tourists on Turkey's energy consumption. The study revealed a unidirectional causal link between tourist numbers and energy consumption. This was achieved by using the bootstrap method to adjust for multiple correlations. The researchers concluded that Turkey's high energy consumption was largely due to the influx of international visitors. Amin et al. (2020) conducted a comparative analysis on multiple South Asian countries from 1995 to 2015, examining the relationship between tourism and energy consumption. The findings indicate a long-term, one-way causal relationship between the increase in visitor numbers and energy consumption. Selvanathan et al. (2021) examined the relationships among tourism, energy consumption, carbon emissions, and gross domestic product in South Asian countries. A study conducted using the panel ARDL and VECM frameworks analyzed data from 1990 to 2014 and revealed a positive relationship between tourism and energy consumption in Bangladesh, India, Nepal, and Pakistan. However, the increasing $CO_2$ emissions pose a significant threat to the integrity of the environment. The emissions are caused by the growing energy consumption resulting from the expansion of the tourist industry in South Asia. Therefore, the environmental quality is endangered.

Shi et al. (2020) discovered a unidirectional causal relationship between primary energy consumption in high-middle-income countries and both visitor expenditures and the net inflow of international tourists over a long-term period. The study revealed a causal relationship between the primary energy use of high-income nations and the per-capita expenditure of foreign tourists. This relationship is short-run and one-way in nature. The study found that the impact of tourism on energy consumption differed based on the gross national product of the countries examined. The article examined the relationship between carbon emissions and the influence of tourism on energy consumption during its calculations. Nepal et al. (2019) employed ARDL and Granger causality analyses to investigate the short and long-term association between tourism receipts, GDP per capita, emissions, energy consumption, and capital formation in Nepal. A one-way causal relationship was discovered between tourism-energy use and a 3.84 % decrease in visitor numbers for each 1 % increase in energy use. This study examines the impact of firewood consumption and reduced reliance on fossil fuels on tourism in Nepal and other developing countries. No association was found between the number of tourists visiting the countries in the European Union and the candidate nations, and the total energy consumption of these nations (Dogan & Aslan, 2017).

Usmani et al. (2021) investigated the relationship between tourism arrivals, tourist expenditure, and economic growth in four developing countries (Brazil, Russia, India, and China) using annual data from 1995 to 2016. The study utilized the Dumitrescu–Hurlin causality test and panel data models. The findings suggest that tourist expenditure positively affects economic growth. The relationship between tourist expenditure and economic growth exhibits bidirectional causality. Khanal et al. (2021) examined the long-term cointegration between international tourist arrivals and primary energy consumption in Australia using data from 1976 to 2018. Several econometric tests, including Augmented Dickey-Fuller, Phillips-Perron, ARDL bound tests, Johansen and Juselius, and Bayer-Hanck cointegration test, were conducted to evaluate the relationship. Additionally, various diagnostic tests were performed. The study found a significant long-run cointegrating relationship between energy consumption and tourist arrivals, gross domestic product, and financial development. Irfan et al. (2023) employed the ARDL bound testing and Gradual shift causality methods to examine the environmental effects of the tourism sector using data from 2001 to 2019. The findings indicate that all sub-sectors of the tourism industry have a significant and positive influence on both energy consumption and economic growth. However, it is worth noting that tourism-related travel has a higher energy consumption compared to other sub-sectors. Pablo-Romero et al. (2023) demonstrated a positive correlation between energy consumption and tourist arrivals in the top 15 countries with the highest international tourist arrivals from 2000 to 2019. Visas et al. (2023) investigated the influence of tourism on energy consumption in the BRICS countries (Brazil, Russia, India, China, and South Africa) using panel data from 1995 to 2014. The empirical analysis employed the Feasible Generalized Least Squares (FGLS) and Panel Corrected Standard Error (PCSE) panel regression techniques. The findings indicate that tourism has a significant and positive effect on energy consumption. Nonetheless, there is a global shift towards technologies that enhance energy efficiency, decreasing reliance on fossil fuels, and transitioning to renewable energy sources. The tourism sector is increasingly prioritizing nature-based tourism as a strategy to minimize energy consumption. For instance, eco-tourism, sustainable tourism, green tourism, agritourism, wildlife tourism, adventure tourism, and geo-tourism. Therefore, it is essential to delve deeper into the relationship between tourism and energy consumption to facilitate effective policy development for green energy in support of sustainable

tourism.

### 2.3. Tourism and $CO_2$ emissions

There is currently a surge of interest among politicians and researchers in investigating the impact of tourism on the natural environment. Pigram (1980) examined the relationship between tourism and the environment and identified potential positive, neutral, or negative impacts on environmental quality. Multiple studies have shown that tourism has a significant and positive impact on $CO_2$ emissions. Tourism may contribute to long-term increases in $CO_2$ emissions through its impact on energy consumption. León et al. (2014) employed a STIRPAT approach on balanced panel data of developed and less developed countries from 1998 to 2006. The study findings indicate that tourism has a substantial impact on $CO_2$ emissions in both less developed and developed nations. Ochoa-Moreno et al. (2022) found a positive correlation between tourism and $CO_2$ emissions in a sample of 20 Latin American countries from 1995 to 2018. Zaman et al. (2016) examined the correlation between $CO_2$ emissions and tourism development in three diverse regions: East Asia & Pacific, EU, and high-income countries from both OECD and Non-OECD. The study found that both tourism and energy use contribute to $CO_2$ emissions. Farooq et al. (2024) used data from Gulf Cooperation Council (GCC) economies from 2000 to 2019. They applied the FMOLS and generalized least squares (GLS) methods to examine the relationship between tourism and environmental degradation. The study found a positive correlation between tourist arrivals and $CO_2$ emissions. Balli et al. (2019) found that tourism in Mediterranean countries from 1995 to 2014 led to an increase in $CO_2$ emissions. Durbarry and Seetanah (2015) investigated the relationship between tourism and travel activities and climate change in Mauritius. They found that an increase in tourist arrivals is associated with a corresponding increase in $CO_2$ emissions. Nwaeze et al. (2023) examined the relationship between tourism developments and $CO_2$ emissions in the EU by analyzing data from 1995 to 2018. The study focused on the top 12 tourist countries in the EU and utilized the Panel ARDL framework to explore the dynamic linkages between these variables. The study showed a positive correlation between tourism and emissions. Nosheen et al. (2021) employed the DOLS method and analyzed time series data from 1995 to 2017. They discovered that tourism in the Asian region had a detrimental effect on the environment, as it led to an increase in $CO_2$ emissions. Balsalobre-Lorente et al. (2020) found that $CO_2$ emissions contribute to climate change, and this effect is amplified by energy consumption, tourism, and economic expansion in OECD countries from 1994 to 2014. Selvanathan et al. (2021) examined the connection between tourism and $CO_2$ emissions in South Asia from 1990 to 2014 using the ARDL model. The study determined that tourism has a positive impact on long-term $CO_2$ emissions. Khan et al. (2020) found that tourism contributes to increased $CO_2$ emissions based on data from 1990 to 2016 for 51 countries involved in the Belt & Road Initiative (BRI). According to Lee and Brahmasrene (2016), tourism in sub-Saharan Africa has a positive impact on carbon emissions. Sharif et al. (2017) examined the relationship between $CO_2$ emissions and tourist arrivals in Pakistan using time series data from 1972 to 2013. The results from ARDL, FMOLS, and DOLS indicate a significant relationship between the number of tourists visiting Pakistan and the country's carbon emissions. Ali et al. (2020) examined the relationship between tourist arrivals and $CO_2$ emissions in Pakistan from 1981 to 2017 using the ARDL approach. The study revealed a negative relationship between international tourism and environmental quality. Katircioglu et al. (2020) found a positive relationship between tourism and $CO_2$ emissions in Cyprus based on data from 1977 to 2015. Sekrafi and Sghaier (2018) examined the correlation between tourism development, energy consumption, and carbon emissions in Tunisia from 1974 to 2014 using the ARDL approach. The study found that tourism has an indirect impact on the environment's quality through energy consumption. Adebayo et al. (2023) found that tourist arrivals in Thailand between 1995 and 2018 were associated with increased environmental degradation. Zhang and Zhang (2021) analyzed data from 30 Chinese provinces spanning the years 2000–2017. The study found that tourism has a positive effect on $CO_2$ emissions. Nepal et al. (2019) found that tourist arrivals in Nepal between 1975 and 2014 are associated with increased environmental degradation. Eyuboglu and Uzar (2020) examined the relationship between $CO_2$ emissions and tourist arrivals in Turkey from 1960 to 2014. The findings suggest that tourism contributes to $CO_2$ emissions. Khanal et al. (2022) examined the correlation between tourism and carbon emissions in Australia using the ARDL method and data from 1976 to 2019. The findings suggest a significant and positive correlation between tourism and carbon emissions in the long term. Jayasinghe and Selvanathan (2021) examined the association between $CO_2$ emissions and international tourist arrivals in India from 1991 to 2018, employing the ARDL model framework. The findings indicate a positive relationship between tourism and $CO_2$ emissions. Solarin (2014) analyzed data from 1972 to 2010 in Malaysia and found a positive relationship between $CO_2$ emissions and economic growth, energy consumption, and tourism. The existing literature indicates that tourism influences $CO_2$ emissions due to the usage of fossil fuels for different tourism activities.

Prior research has indicated that tourism has negative environmental impacts, although certain studies have found evidence of tourism's potential to decrease $CO_2$ emissions. Leitão and Lorente (2020) examined the relationship between tourism arrivals and $CO_2$ emissions in the EU using panel FMOLS, panel DOLS, and GMM-System estimators. The study found that tourism arrivals led to a decrease in $CO_2$ emissions. Dogan and Aslan (2017) employed various econometric techniques, including OLS-fixed-effects, FMOLS, DOLS, and the group-mean estimator, to examine the relationship between $CO_2$ emissions and tourism in EU countries. The study determined that tourism helps to reduce $CO_2$ emissions. Lee and Brahmasrene (2013) conducted a study using panel data from EU countries spanning the years 1988–2009. They utilized cointegration tests to examine the effects of tourism on economic growth and $CO_2$ emissions. The study found that international tourism has a positive effect on economic growth in the EU and contributes to reducing the region's carbon emissions. Rahman et al. (2022) employed the CS-ARDL method to examine the impact of tourism on the environment in the top ten tourist countries worldwide between 1972 and 2021. The study determined that increased tourism activity has a beneficial effect on environmental quality. Aziz et al. (2020) employed yearly data spanning from 1995 to 2018 for the BRICS nations. The results of the FMOLS and DOLS estimation indicate a negative relationship between tourism and $CO_2$ emissions. Ullah et al. (2023) found that tourism is negatively correlated with $CO_2$ emissions across nations based on data from 1995 to 2018 in the CS-ARDL test. Jebli et al. (2019) reported that tourism reduced emissions in 22 Central and South American countries from 1995 to 2010. Akadiri et al. (2021) investigated the correlation between carbon emissions and the expansion of international tourism in 16 tourism-dependent island nations from 1995 to 2016. The study findings suggest that international tourism has a long-term negative impact on carbon emissions. Sherafatian-Jahromi et al. (2017) found that tourism in Southeast Asia contributes to increased $CO_2$ emissions. Shakouri et al. (2017) investigated the impact of tourism on $CO_2$ emissions in the Asia-Pacific region from 1995 to 2013 using panel data. The panel GMM analysis found that tourist arrivals have a negative impact on $CO_2$ emissions. Wei and Lihua (2023) found that tourism mitigates $CO_2$ emissions based on data from 1995 to 2018. Voumik et al. (2023) examined the impact of tourism on $CO_2$ emissions in 40 Asian countries from 1995 to 2019. The results of the CS-ARDL model indicate that tourism has the potential to reduce $CO_2$ emissions. Katircioglu et al. (2014) discovered a negative correlation between tourism and $CO_2$ emissions in Singapore. Xiangyu et al. (2021) investigated the asymmetric relationship between tourist arrivals and $CO_2$ emissions in the USA using monthly data from 2000 to 2018. The study utilized the quantile ARDL approach to demonstrate a negative relationship between tourist arrivals and $CO_2$ emissions. Yue et al.

(2021) employed the bootstrapping ARDL approach to demonstrate that tourism in Thailand resulted in a decrease in $CO_2$ emissions, thereby reducing environmental damage. Paramati et al. (2017) discovered that tourism has differing effects on $CO_2$ emissions in the Eastern and Western EU based on time series data. Ghosh (2020) utilized the FMOLS, DOLS, and PMG estimators to examine the effects of tourism on environmental quality in a panel of 95 countries using annual data from 1995 to 2014. The study observed a negative correlation between tourism and $CO_2$ emissions in high-income countries, but a positive correlation in middle-income countries. Azam et al. (2018) investigated the impact of tourist arrivals on $CO_2$ emissions-induced environmental pollution in Malaysia, Thailand, and Singapore from 1990 to 2014. The empirical findings indicate that tourism has a significant positive impact on environmental pollution in Malaysia, while an inverse relationship between tourism and environmental pollution was observed in Thailand and Singapore. Dogru et al. (2020) found that tourism development has both negative and significant effects on $CO_2$ emissions in Canada, Czechia, and Turkey, but positive and significant effects in Italy, Luxembourg, and the Slovak Republic. Mehmood et al. (2022) analyzed data from 1995 to 2020 and observed that tourism had a negative effect on $CO_2$ emissions in Pakistan and Nepal, but a positive effect in Sri Lanka and India. Sghaier et al. (2019) found that tourism has a detrimental impact on environmental quality in Egypt, a beneficial impact in Tunisia, and a neutral impact in Morocco. The review of the literature indicates that tourism can improve environmental quality by promoting eco-friendly transportation, sustainable accommodations, and carbon offset initiatives, thereby reducing $CO_2$ emissions.

Koçak et al. (2020) investigated the influence of tourism developments on $CO_2$ emissions in the most frequently visited countries between 1995 and 2014. The empirical findings suggest that tourism arrivals contribute to an increase in $CO_2$ emissions, whereas tourism receipts are associated with a decrease in $CO_2$ emissions. Shi et al. (2020) found that a 1 % increase in the net inflow of international tourists led to a 0.072 % increase in $CO_2$ emissions in low-income countries and a 0.059 % increase in high-income countries. Paramati et al. (2016) found that the reduction of $CO_2$ emissions caused by tourism is occurring at a faster rate in developed economies compared to developing economies. Balsalobre-Lorente et al. (2020) found that once economies reach a certain level of development in their tourism industry, international tourism can lead to environmental improvements. This is based on a long-term analysis of the relationship between economic growth, international tourism, energy consumption, and $CO_2$ emissions in developed countries. The examination of current literature reveals a complex issue regarding the true effects of tourism on environmental quality, as these impacts can differ significantly across regions and depend on the level of environmental investment. Therefore, it necessitates additional inquiry to explore the impacts of different tourism indicators on environmental quality.

### 2.4. Literature gap

The empirical literature suggests that tourism can have both positive and negative environmental impacts. The existing literature on the relationship between tourism and carbon emissions has produced inconclusive results regarding the true impact of tourism. Malaysia experiences a high influx of tourists, resulting in increased energy consumption and subsequent $CO_2$ emissions. Therefore, it is crucial to assess the relationship between tourism and $CO_2$ emissions in Malaysia. While many studies have examined the economic and environmental impacts of tourism, there is a lack of research on the influence of tourism within the energy-economy-environment framework, specifically in Malaysia. Moreover, prior research has focused solely on tourist arrivals as a measure of tourism, neglecting the significance of tourism expenditures and tourism receipts. There is a research gap in the existing literature regarding the accurate impact of various tourism indicators using econometric methods. Furthermore, there is a lack of research on the impact of tourism indicators on economic progress, carbon neutrality, and SDGs. The present study aims to investigate the relationship between tourist arrivals, tourism expenditures, and tourism receipts, and their impact on the growth of the Malaysian economy, energy consumption, and carbon emissions, addressing gaps in the existing literature. This study distinguishes itself from similar efforts in two ways, enabling it to address a gap in the current literature. This study aims to investigate the relationship between tourism, energy efficiency, carbon neutrality, and environmental sustainability in Malaysia. It is the first study to utilize econometric methods within a diverse energy-economy-emission framework to achieve these objectives. This study applies econometric approaches to examine the effects of tourist arrivals, tourism expenditures, and tourism receipts on energy use, economic growth, and environmental sustainability in Malaysia. The novelty and scientific contribution of this research lie in its application of these approaches.

## 3. Methodology

### 3.1. Data

This paper aims to examine the effects of tourist arrivals, tourism expenditures, and tourism receipts on energy use, economic growth, and carbon emissions in Malaysia, both in the short and long term. This study analyzed annual time-series data from 1995 to 2020. The World Development Indicator (WDI) provided the data for all study variables. In order to reduce the variance of the series, the study employed the logarithmic transformations of the variable of interest. Table 1 provides the definitions, units of measurement, and data sources for each variable. Fig. 1 displays the annual trends of international tourism indicators in Malaysia.

### 3.2. Theoretical framework, empirical model, and analysis flowchart

The theoretical significance lies in the examination of the impacts of tourism development on energy consumption, economic growth, and environmental sustainability. Tourism-related businesses, including those in hospitality, accommodation, and catering, generate employment opportunities that address unemployment and promote growth in manufacturing and service sectors. This, in turn, contributes to the economies of both developed and developing countries. Tourism development is associated with higher tourist arrivals, leading to increased energy consumption for transportation, accommodation, and tourist activities. The tourism industry relies on fossil fuels for transportation, accommodation, and various activities, resulting in an increase in carbon emissions. An increase in tourism volume may enhance ecotourism, green tourism, and sustainable tourism. Nations are increasing their investments in natural reserves, forests, and parks in order to attract more international tourists. Tourism impacts carbon

**Table 1**
Variables including their descriptions, logarithmic structures, measurement units, and data sources.

| Variables | Description | Logarithmic structures | Measurement units | Source |
|---|---|---|---|---|
| EU | Energy use | LEU | Kg of oil equivalent per capita | WDI |
| GDP | Economic growth | LGDP | GDP per capita (current US$) | |
| $CO_2$ | $CO_2$ emissions | LCO2 | Metric tons per capita | |
| TA | Tourist arrivals | LTA | Number of tourist arrivals | |
| TE | Tourism expenditures | LTE | Current US$ | |
| TR | Tourism receipts | LTR | Current US$ | |

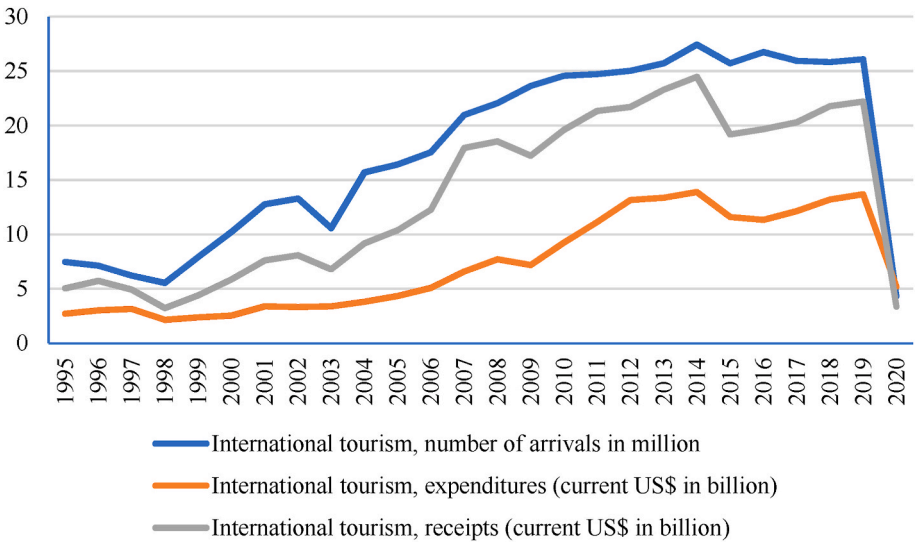


**Fig. 1.** Annual trends of international tourism indicators in Malaysia.

emissions and the environment. The literature indicates that foreign visitors can have both positive and negative impacts on the ecosystem. The primary factors contributing to this are the energy sources utilized in tourism and the emphasis on sustainable tourism investment. In addition, countries can allocate funds from tourism expenditures and receipts towards investments in environmental sustainability, pollution reduction, and green tourism. Tourism expenditures refer to the aggregate sum of money expended by visitors or on their behalf for goods and services while visiting a particular country. This encompasses expenditures made prior to, during, and subsequent to the journey, encompassing costs associated with transportation, lodging, dining, tourist attractions, shopping, and entertainment. Tourism receipts refer to the monetary earnings that a destination country generates from international visitors. Payments encompass transportation, goods, and services, and may also encompass prepayments for goods and services. Tourism expenditures and receipts can contribute to the economic growth of the destination country, but they may also lead to increased energy consumption. Investing tourism receipts in reducing environmental pollution can contribute to achieving environmental sustainability and promoting sustainable and green tourism development.

This study investigates the effects of tourism on energy consumption, economic growth, and environmental sustainability. Three indicators of tourism (tourist arrivals, tourism expenditures, and tourism receipts) were selected to evaluate their effects on energy, the economy, and the environment. Three distinct models were employed to analyze these impacts:

$$\text{Energy model: } EU = f(TA, TE, TR) \tag{1}$$

$$\text{Economy model: } GDP = f(TA, TE, TR) \tag{2}$$

$$\text{Emission model: } CO_2 = f(TA, TE, TR) \tag{3}$$

The ensuing equations express the econometric model:

$$\text{Energy model}: EU_t = \tau 0 + \tau_1 TA_t + \tau_2 TE_t + \tau_3 TR_t + \varepsilon_t \tag{4}$$

$$\text{Economy model}: GDP_t = \tau_0 + \tau_1 TA_t + \tau_2 TE_t + \tau_3 TR_t + \varepsilon t \tag{5}$$

$$\text{Emission model}: CO2_t = \tau_0 + \tau_1 TA_t + \tau_2 TE_t + \tau_3 TR_t + \varepsilon t \tag{6}$$

where $\tau_0$ and $\varepsilon_t$ are the intercept and the error term. In addition, $\tau_1$, $\tau_2$, and $\tau_3$ represent the coefficients.

The equation can be extended into the natural logarithm form by the following equations:

$$\text{Energy model}: LEU_t = \tau_0 + \tau_1 LTA_t + \tau_2 LTE_t + \tau_3 LTR_t + \varepsilon t \tag{7}$$

$$\text{Economy model}: LGDP_t = \tau_0 + \tau_1 LTA_t + \tau_2 LTE_t + \tau_3 LTR_t + \varepsilon t \tag{8}$$

$$\text{Emission model}: LCO2_t = \tau_0 + \tau_1 LTA_t + \tau_2 LTE_t + \tau_3 LTR_t + \varepsilon t \tag{9}$$

Fig. 2 illustrates the flow chart of the analysis procedure. This study assessed the stationarity of the data by conducting a unit root test after selecting the data range and constructing the econometric models. Once

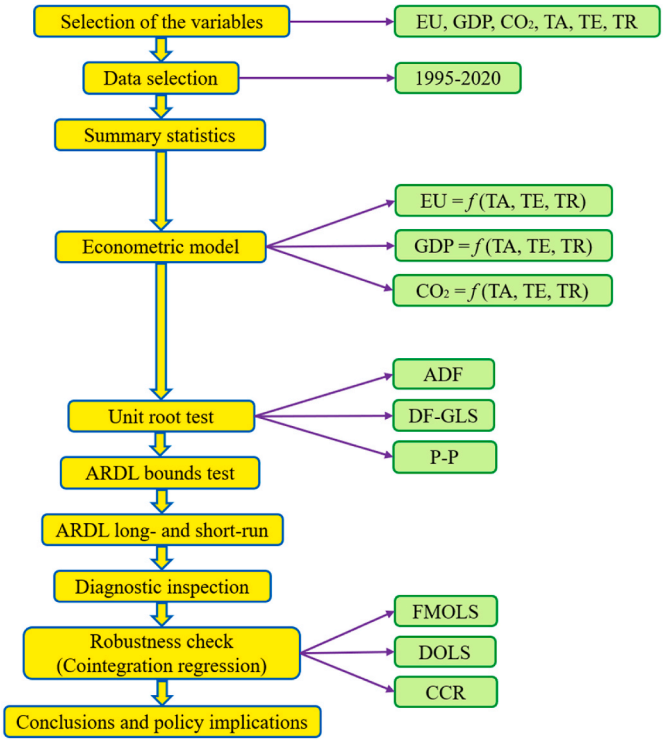


**Fig. 2.** The analysis procedure flowchart of the study.

the stationarity of the dataset is confirmed, the analysis is carried out using the ARDL framework, which consists of two steps. The first step involves conducting the ARDL bounds test to determine the presence of cointegration among the variables. Once cointegration is confirmed through the ARDL bounds test, the next step is to perform long- and short-run analysis using the ARDL model. This study employed the DOLS, FMOLS, and CCR regression models to verify the long-term coefficients derived from the ARDL estimation. The analysis procedures generated policy implications from the study's outcomes, limitations, and future research directions.

### 3.3. Unit root test

This study examines the relationships between the dependent variable and its explanatory variables to determine whether the dataset is integrated at I(0) or I(1). Furthermore, not all regressors require a seasonal influence or inclusion by order one. Avoiding the I(2) sequence is not valid and can lead to misleading results. Moreover, the presence of a non-stationary variable can lead to inaccurate results. Nevertheless, the transition to I(2) is unprecedented and raises concerns due to the limited sample size. This study detected the presence of an autoregressive unit root through the application of three tests: the Augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1979), the Dickey-Fuller generalized least squares (DF-GLS) test (Elliott et al., 1996), and the Phillips-Perron (P-P) test (Phillips & Perron, 1988).

### 3.4. ARDL method

The ARDL bounds analysis procedure of cointegration (Pesaran et al., 2001) was employed to examine the long-term relationship between the parameters. The cointegration test discussed here offers several advantages compared to conventional methods in terms of the integration sequence (Raihan, 2024). This approach can be used if the parameters are found to be constant at either the I(1) or I(0) level. The ARDL bounds assessment empirical model employs an adequate number of lags within a general-to-specific modeling framework to effectively capture the data generation process. The ARDL framework allows for the calculation of the ARDL F-statistic to examine the presence of cointegration. This is done by using a varying number of lags for each variable. The ARDL F-statistic exceeding the upper critical estimate indicates the presence of cointegration among the parameters. If the ARDL F-statistic is below the lower critical bound, then the variables do not show cointegration. When the ARDL F-statistic falls between the upper and lower critical values, the empirical conclusions will lack persuasiveness. The equations below represent the approximate models used in the ARDL bounds analysis method for investigating cointegration:

Energy model:

$$\Delta LEU_t = \tau_0 + \tau_1 LEU_{t-1} + \tau_2 LTA_{t-1} + \tau_3 LTE_{t-1} + \tau_4 LTR_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LEU_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LTA_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LTE_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LTR_{t-i} + \varepsilon_t \quad (10)$$

Economy model:

$$\Delta LGDP_t = \tau_0 + \tau_1 LGDP_{t-1} + \tau_2 LTA_{t-1} + \tau_3 LTE_{t-1} + \tau_4 LTR_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LGDP_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LTA_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LTE_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LTR_{t-i} + \varepsilon_t \quad (11)$$

Emission model:

$$\Delta LCO2_t = \tau_0 + \tau_1 LCO2_{t-1} + \tau_2 LTA_{t-1} + \tau_3 LTE_{t-1} + \tau_4 LTR_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LCO2_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LTA_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LTE_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LTR_{t-i} + \varepsilon_t \quad (12)$$

The symbol Δ represents the first difference operator, while q denotes the optimal lag length.

The ARDL bounds testing approach can be linearly transformed to derive the error correction model (ECM). This method produces reliable empirical results even with small sample sizes. The ECM integrates short-run subtleties with long-term stability in order to preserve the overall picture. This procedure isolates the cointegrating vectors resulting from the presence of multiple cointegrating vectors in the empirical model (Raihan & Bari, 2024). The coefficient of ECM is denoted by the symbol θ. When the ECM is both negative and statistically significant, it is necessary to adjust the variance in order to achieve equilibrium. This study calculated the short-run coefficients of the parameters using the specified equations, following the establishment of the long-term relationship between the series.

Energy model:

$$\Delta LEU_t = \tau_0 + \tau_1 LEU_{t-1} + \tau_2 LTA_{t-1} + \tau_3 LTE_{t-1} + \tau_4 LTR_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LEU_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LTA_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LTE_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LTR_{t-i} + \theta ECM_{t-1} + \varepsilon_t \quad (13)$$

Economy model:

$$\Delta LGDP_t = \tau_0 + \tau_1 LGDP_{t-1} + \tau_2 LTA_{t-1} + \tau_3 LTE_{t-1} + \tau_4 LTR_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LGDP_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LTA_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LTE_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LTR_{t-i} + \theta ECM_{t-1} + \varepsilon_t \quad (14)$$

Emission model:

$$\Delta LCO2_t = \tau_0 + \tau_1 LCO2_{t-1} + \tau_2 LTA_{t-1} + \tau_3 LTE_{t-1} + \tau_4 LTR_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LCO2_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LTA_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LTE_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LTR_{t-i} + \theta ECM_{t-1} + \varepsilon_t \quad (15)$$

### 3.5. Robustness check

This study employed alternative cointegration regression methods, including FMOLS (Hansen & Phillips, 1990), DOLS (Stock & Watson, 1993), and CCR test (Park, 1992), to assess the robustness of ARDL results. FMOLS uses a semi-parametric method to analyze the long-run elements and allows for resolving common econometric challenges, including endogeneity, omitted variable bias, serial correlation, and estimation errors, even when dealing with small sample data. It also works better than other cointegration methods because it gives more accurate t-statistics for long-term analysis (Hansen & Phillips, 1990). The DOLS includes both lags and leads of regressors into the error covariance matrix, enabling the reduction of endogeneity and enhancing the accuracy of standard errors (Stock & Watson, 1993). In addition, the estimators derived from the DOLS have robust asymptotic properties, thereby providing robust statistical accuracy. Furthermore, the DOLS provides accurate estimations of the endogenous factor based on independent parameters across various degrees of integration in the context of systems with mixed orders of integration. Finally, the CCR is considered another technique for estimating cointegrating vectors

within I(1) process models. Although there is some similarity with FMOLS, the main difference lies in their respective transformation approach. The FMOLS technique involves applying transformations to both the parameters and the data, while the CCR technique mainly concentrates on transforming the data (Park, 1992). It is remarkable that preceding investigations effectively documented the robustness of the FMOLS, DOLS, and CCR methodologies and their suitability for assessing the sensitivity of ARDL findings (Idroes et al., 2024; Khan & Liu, 2023; Pattak et al., 2023).

## 4. Results and discussion

Table 2 presents the results of tests conducted to assess the normal distribution of the data, along with a data description. Given the skewness values close to zero, it is evident that the dataset follows a normal distribution. Kurtosis values below 3 indicate the presence of platykurtic variables. Both the Jarque-Bera test and the probability values indicate that all variables exhibited a normal distribution. The investigation's findings indicated that none of the variables significantly deviated from their means.

The evaluation of the unit root test provides important information on the integration characteristics of the parameters. The provided information is necessary for the application of techniques in establishing a sustainable long-term interrelationship. The ADF, DF-GLS, and P-P unit root tests were used to assess the integration properties of the series. The stationarity test results are summarized in Table 3. Based on the canonical unit root tests, LEU, LGDP, LTA, LTE, and LTR showed evidence of having a unit root at the initial level before becoming stationary after the first difference. The P-P tests indicated that LCO2 was stationary at level I(0) and became I(1) after taking the first difference. The ADF and DF-GLS tests showed that LCO2 was not stationary at the level, but became stationary after the first difference was taken.

The ARDL bounds test was conducted to examine the temporal relationship between the variables, taking into account the results of the unit root test. The findings of the cointegration analysis are presented in Table 4. The results indicate that the F-statistic values for the energy mode (15.86), economy model (13.57), and emission model (12.07) exceeded the critical values at the upper limits of 1 %, 5 %, and 10 %. Hence, it can be inferred that tourism factors exhibit a long-term correlation with energy consumption, economic development, and carbon emissions.

The study first established a long-term relationship using the bound test. Subsequently, the ARDL method was employed to analyze the long-term and short-term dynamics of the relationships between tourism indicators and energy, economy, and environment. Table 5 presents the results of both the long-run and short-run estimations of the ARDL. The energy model's results showed positive coefficients for LTA, LTE, and LTR. The findings suggest that a 1 % increase in tourist arrivals, tourism expenditures, and tourism receipts would result in a long-term increase in energy consumption of 0.46 %, 0.47 %, and 0.64 %, respectively. In the short term, the corresponding increases would be 0.30 %, 0.31 %, and 0.51 %. The $R^2$ and adjusted $R^2$ values of the long-run estimates suggest a strong fit of the regression model to the data. In addition, the ECM coefficient is significantly negative, suggesting that the long-run equilibrium is achieved after short-run errors are corrected by 60 %.

In addition, the results of the economic model showed significantly positive coefficients for LTA, LTE, and LTR. The study found that a 1 % increase in tourist arrivals, tourism expenditures, and tourism receipts would have a positive impact on long-term economic growth, with increases of 0.45 %, 0.47 %, and 0.54 % respectively. In the short term, the impact would be slightly lower, with increases of 0.26 %, 0.32 %, and 0.40 % respectively. The $R^2$ and adjusted $R^2$ values of the long-run estimates suggest a strong fit of the regression model to the data. In addition, the ECM coefficient is significantly negative, suggesting that the long-run equilibrium is achieved after short-run errors are corrected by 65 %.

Furthermore, the emission model results showed positive coefficients for LTA and LTE, but negative coefficients for LTR. The results showed that a 1 % rise in tourist arrivals and tourism expenditures would lead to a long-term increase in $CO_2$ emissions of 0.32 % and 0.26 %, respectively. In the short term, the increase would be 0.39 % for tourist arrivals and 0.29 % for tourism expenditures. The findings suggest that a 1 % rise in tourism receipts has the potential to decrease $CO_2$ emissions by 0.10 % in the long term and 0.03 % in the short term. The $R^2$ and adjusted $R^2$ values of the long-run estimates suggest a strong fit of the regression model to the data. Furthermore, the ECM coefficient is significantly negative, suggesting that the long-run equilibrium is achieved after a 57 percent adjustment of short-run errors. The coefficients in all three models indicate that tourism receipts have a greater influence compared to tourist arrivals and tourism expenditure.

In addition, various diagnostic tests were conducted to assess the validity of the models (Table 6). The Lagrange Multiplier test indicates the absence of serial correlation for all three models. The models passed the stability test as their residuals exhibited normal distribution, as confirmed by the Jarque-Bera normality test. The Breusch-Pagan-Godfrey heteroscedasticity test found no evidence to reject the null hypothesis of homoscedasticity, indicating the absence of heteroscedasticity. The conclusion derived from the Ramsey RESET test suggests that the regression has been correctly specified for all three models. The p-values of the F-statistic for all three models are 0.0000, indicating that the linear relationships in the models are statistically significant.

In addition, an endogenous problem may occur when the error component in the equation is associated with one or more forecasting variables. Regression methods cannot produce consistent estimates when the models have an endogeneity problem. The study employed the Hausman (1978) endogeneity test, also referred to as the Hausman specification test, to ascertain the presence of this issue in the statistical models. Excessive instruments for system observations can lead to overfitting of endogenous variables in time series estimates, potentially compromising the test's ability to detect excessive constraints. The results from Table 6 indicate that the chi-square test coefficient in the Hausman specification test is not statistically significant. This supports the acceptance of the null hypothesis, suggesting that the random effect regression model is suitable and there are no endogenous issues with the

**Table 2**
Statistical summaries of the variables.

| Variables | LEU | LGDP | LCO2 | LTA | LTE | LTR |
|---|---|---|---|---|---|---|
| Mean | 7.8227 | 8.8140 | 1.8439 | 16.5494 | 22.5110 | 23.1445 |
| Median | 7.8444 | 8.8757 | 1.9073 | 16.7696 | 22.4917 | 23.4006 |
| Maximum | 8.0865 | 9.3176 | 2.0437 | 17.1274 | 23.3547 | 23.9207 |
| Minimum | 7.4482 | 8.1044 | 1.4554 | 15.2818 | 21.4934 | 21.8979 |
| Std. Dev. | 0.1822 | 0.4225 | 0.1716 | 0.5826 | 0.6563 | 0.6760 |
| Skewness | −0.3666 | −0.2024 | −0.7137 | −0.7339 | −0.0373 | −0.4485 |
| Kurtosis | 2.1073 | 1.4616 | 2.2662 | 2.1629 | 1.4452 | 1.7091 |
| Jarque-Bera | 1.4458 | 2.7414 | 2.7907 | 3.0932 | 2.6249 | 2.6770 |
| Probability | 0.4853 | 0.2539 | 0.2477 | 0.2130 | 0.2692 | 0.2622 |

Notes: LEU = Eenergy use, LGDP = Economic growth, LCO2 = $CO_2$ emissions, LTA = Tourist arrivals, LTE = Tourism expenditures, LTR = Tourism receipts.

**Table 3**
Unit root test results.

| Variables | ADF | | DF-GLS | | P-P | |
|---|---|---|---|---|---|---|
| | I(0) | I(1) | I(0) | I(1) | I(0) | I(1) |
| LEU | −1.592 | −5.591*** | −0.401 | −5.234*** | −2.567 | −9.247*** |
| LGDP | −0.714 | −4.422*** | −0.483 | −4.493*** | −0.701 | −4.405*** |
| LCO2 | −2.528 | −5.809*** | −0.992 | −4.810*** | −5.085*** | −6.010*** |
| LTA | −1.291 | −3.698*** | −1.263 | −3.512*** | −1.291 | −3.698*** |
| LTE | −1.315 | −4.223*** | −1.083 | −3.664*** | −1.315 | −4.223*** |
| LTR | −1.347 | −4.602*** | −1.296 | −3.828*** | −1.347 | −4.602*** |

Notes: ADF = Augmented Dickey-Fuller, DF-GLS = Dickey-Fuller generalized least squares, P-P = Phillips-Perron, LEU = Eenergy use, LGDP = Economic growth, LCO2 = $CO_2$ emissions, LTA = Tourist arrivals, LTE = Tourism expenditures, LTR = Tourism receipts, ***p < 0.01.

**Table 4**
ARDL bounds test results.

| Test statistic | Estimate | Significance levels | I(0) | I(1) |
|---|---|---|---|---|
| Energy model: dependent variable LEU | | | | |
| F-statistic | 15.8627 | 10 % | 2.37 | 3.20 |
| K | 3 | 5 % | 2.79 | 3.67 |
| | | 2.5 % | 3.15 | 4.08 |
| | | 1 % | 3.65 | 4.66 |
| Economy model: dependent variable LGDP | | | | |
| F-statistic | 13.5669 | 10 % | 2.37 | 3.20 |
| K | 3 | 5 % | 2.79 | 3.67 |
| | | 2.5 % | 3.15 | 4.08 |
| | | 1 % | 3.65 | 4.66 |
| Emission model: dependent variable LCO2 | | | | |
| F-statistic | 12.0715 | 10 % | 2.37 | 3.20 |
| K | 3 | 5 % | 2.79 | 3.67 |
| | | 2.5 % | 3.15 | 4.08 |
| | | 1 % | 3.65 | 4.66 |

Notes: LEU = Eenergy use, LGDP = Economic growth, LCO2 = $CO_2$ emissions, K = Lag length.

regression models.

This study employed the cumulative sum (CUSUM) and CUSUM of squares tests to assess the presence of a stable relationship over an extended duration. The CUSUM and CUSUM of squares tests were used to examine the regression coefficients and residuals. The results of CUSUM and CUSUM of squares tests for all three models are shown in Fig. 3. The coefficients of all three models' plots were within the critical bounds and met the 5 % significance level. None of the lines exceeded the critical bound during the entire process. The coefficients remained unchanged, thus confirming the stability of the models.

In addition, the FMOLS, DOLS, and CCR tests were employed to assess the reliability of the findings derived from the ARDL estimation (Table 7). The study showed that the FMOLS, DOLS, and CCR results were consistent and reliable. Ultimately, they yielded the same outcomes as the ARDL simulations. The sign conventions of the coefficients were consistent with those of the economic model. The robustness check findings suggest that tourist arrivals and tourism expenditures in Malaysia are associated with increased energy consumption, economic growth, and $CO_2$ emissions. In the long run, a 1 % increase in tourist arrivals would increase energy use by 0.4 %, increase economic growth by 0.4 %, and increase carbon emissions by 0.3 %. Besides, a 1 % increase in tourism expenditure would increase energy use by 0.4 %, increase economic growth by 0.5 %, and increase carbon emissions by 0.2 % in the long run. Moreover, tourism receipts were found to have a positive impact on economic growth and energy consumption. A 1 % increase in tourism receipts would lead to a 0.5 % increase in both economic growth and energy consumption. However, the findings indicate a significant negative association between tourism receipts and

**Table 5**
ARDL long and short-run results.

| Variables | Long-run | | | Short-run | | |
|---|---|---|---|---|---|---|
| | Coefficient | t-statistic | p-value | Coefficient | t-statistic | p-value |
| Energy model: dependent variable LEU | | | | | | |
| LTA | 0.4560** | 2.3910 | 0.0176 | 0.2979*** | 3.3910 | 0.0074 |
| LTE | 0.4731*** | 5.3132 | 0.0001 | 0.3071*** | 7.3322 | 0.0000 |
| LTR | 0.6359** | 2.7772 | 0.0342 | 0.5137*** | 3.8724 | 0.0039 |
| C | 4.8250 | 1.8182 | 0.1003 | – | – | – |
| ECM (−1) | – | – | – | −0.6038*** | −4.9725 | 0.0009 |
| $R^2$ | 0.9989 | | | | | |
| Adjusted $R^2$ | 0.9925 | | | | | |
| Economy model: dependent variable LGDP | | | | | | |
| LTA | 0.4485** | 4.5862 | 0.0195 | 0.2585** | 4.8231 | 0.0119 |
| LTE | 0.4681*** | 8.2145 | 0.0007 | 0.3150*** | 6.9724 | 0.0006 |
| LTR | 0.5430** | 4.0230 | 0.0276 | 0.4047** | 4.6946 | 0.0188 |
| C | 5.7039 | 1.6472 | 0.1036 | – | – | – |
| ECM (−1) | – | – | – | −0.649*** | −5.8049 | 0.0001 |
| $R^2$ | 0.9994 | | | | | |
| Adjusted $R^2$ | 0.9961 | | | | | |
| Emission model: dependent variable LCO2 | | | | | | |
| LTA | 0.3152*** | 4.9589 | 0.0001 | 0.3924*** | 4.9456 | 0.0018 |
| LTE | 0.2608*** | 4.1136 | 0.0005 | 0.2873*** | 4.589 | 0.0067 |
| LTR | −0.0972*** | −5.0582 | 0.0001 | −0.0329*** | −4.6521 | 0.0035 |
| C | 2.6889 | 1.7677 | 0.1071 | – | – | – |
| ECM (−1) | – | – | – | −0.5693*** | −5.1282 | 0.0004 |
| $R^2$ | 0.9936 | | | | | |
| Adjusted $R^2$ | 0.9665 | | | | | |

Notes: LEU = Eenergy use, LGDP = Economic growth, LCO2 = $CO_2$ emissions, LTA = Tourist arrivals, LTE = Tourism expenditures, LTR = Tourism receipts, ECM = Error correction model, ***p < 0.01, **p < 0.05.

**Table 6**
The results of the diagnostic tests.

| Diagnostic tests | Coefficient | p-value | Decision |
|---|---|---|---|
| Energy model: dependent variable LEU | | | |
| Lagrange Multiplier test | 1.7981 | 0.1199 | No serial correlation |
| Breusch-Pagan-Godfrey test | 2.0160 | 0.1410 | No heteroscedasticity |
| Jarque-Bera test | 0.5020 | 0.7899 | Residuals are normally distributed |
| Ramsey RESET test | 1.0781 | 0.1014 | Regression is properly specified |
| F-statistic | 30.6182 | 0.0000 | The linear relationship is significant |
| Hausman specification test | 2.2572 | 0.6122 | No endogenous problem |
| Economy model: dependent variable LGDP | | | |
| Lagrange Multiplier test | 1.4199 | 0.2651 | No serial correlation |
| Breusch-Pagan-Godfrey test | 0.9367 | 0.1435 | No heteroscedasticity |
| Jarque-Bera test | 0.4457 | 0.8002 | Residuals are normally distributed |
| Ramsey RESET test | 1.2623 | 0.1059 | Regression is properly specified |
| F-statistic | 28.2464 | 0.0000 | The linear relationship is significant |
| Hausman specification test | 2.1958 | 0.4666 | No endogenous problem |
| Emission model: dependent variable LCO2 | | | |
| Lagrange Multiplier test | 1.4026 | 0.1340 | No serial correlation |
| Breusch-Pagan-Godfrey test | 1.6674 | 0.1727 | No heteroscedasticity |
| Jarque-Bera test | 0.4587 | 0.7951 | Residuals are normally distributed |
| Ramsey RESET test | 1.6432 | 0.1887 | Regression is properly specified |
| F-statistic | 29.9012 | 0.0000 | The linear relationship is significant |
| Hausman specification test | 2.5086 | 0.5053 | No endogenous problem |

Notes: LEU = Eenergy use, LGDP = Economic growth, LCO2 = $CO_2$ emissions, RESET = Regression equation specification error test.

$CO_2$ emissions, suggesting that tourism receipts have the potential to reduce emissions. The findings suggest that a 1 % increase in tourism receipts might cut carbon emissions by 0.08 % in the long run. The $R^2$ and adjusted $R^2$ values of the FMOLS, DOLS, and CCR estimation for all three models are more than 0.9 suggesting a strong fit between the regression models and the data.

In summary, the value proposition derived from the approaches related to energy, economy, and emission models revealed that, of the three tourism indicators, tourism receipts exhibited the greatest potential for enhancing economic growth and stimulating energy demand, with tourism expenditures and tourist arrivals following in significance. Conversely, in the context of environmental degradation linked to rising carbon emissions, the number of tourist arrivals exhibited a greater magnitude than tourism expenditures. However, this investigation demonstrated that tourism receipts lead to a reduction in carbon emissions. Tourism receipts can contribute to improving environmental quality and reducing emissions by funding sustainable infrastructure, conservation projects, and green technologies. Revenue from tourism can be reinvested in eco-friendly transportation systems, renewable energy sources, and waste management solutions that lower carbon footprints. Additionally, destinations that prioritize sustainable tourism often implement policies encouraging energy efficiency, carbon offset programs, and the preservation of natural habitats, reducing overall emissions. By supporting eco-tourism and responsible travel initiatives, tourism receipts help shift economies toward greener practices, ensuring long-term environmental benefits while maintaining economic growth.

In the last 30 years, Malaysia has experienced a significant rise in tourist arrivals, income growth, energy consumption, and $CO_2$ emissions. The number of tourists, tourism expenditures, and tourism receipts in a country increased by over five times in 2019 compared to 1991. Additionally, the country's GDP per capita increased by approximately three times during the same period (World Bank, 2024). Moreover, individual energy consumption increased by 27 %, accompanied by a fourfold increase in $CO_2$ emissions (World Bank, 2024). The relationship between tourism development and economic activity is straightforward: an increase in tourism development leads to a corresponding increase in economic activity and production, resulting in higher energy consumption (Leung & Ko, 2025; Urbee et al., 2025; Zhu, 2025). Tourism relies on additional forms of energy, such as oil and electricity, to support its infrastructure, facilities, and activities. Furthermore, transportation related to tourism significantly contributes to overall energy consumption. Tourism development leads to increased energy demand due to higher tourist arrivals, tourism expenditures, and tourism receipts.

The study findings suggest a positive relationship between tourist arrivals, tourism expenditure, and tourism receipts with economic growth and energy consumption. The positive relationship between tourism indicators and economic growth is confirmed by several studies. Puah et al. (2018) demonstrated that tourism receipts and capital investment in the tourism industry exert substantial positive effects on the economic growth of Malaysia. In addition, Perles-Ribes et al. (2017), Khan (2020), Naseem (2021), and Cannonier and Burke (2019) have all found that tourist arrivals, tourism expenditure, and tourism receipts have a positive impact on economic growth in Spain, Italy, Saudi Arabia, and Caribbean countries, respectively. Usmani et al. (2021) discovered a positive relationship between tourist expenditure and economic growth in Brazil, Russia, India, and China. Furthermore, Khanal et al. (2021), Irfan et al. (2023), Pablo-Romero et al. (2023), and Visas et al. (2023) have provided evidence supporting the positive relationship between tourism indicators and energy consumption.

The study findings indicate that the growing number of international visitors to Malaysia and their increased tourism expenditure may lead to higher energy consumption, resulting in elevated emissions and potential environmental harm. The main reason for the increasing effect of carbon emissions on tourist arrivals can be attributed to transport services. The positive relationship between tourist arrivals, tourist expenditure, and $CO_2$ emissions is supported by several studies (Adebayo et al., 2023; Azam et al., 2018; Eyuboglu & Uzar, 2020; Farooq et al., 2024; Jayasinghe & Selvanathan, 2021; Khanal et al., 2022; Nosheen et al., 2021; Nwaeze et al., 2023; Ochoa-Moreno et al., 2022; Selvanathan et al., 2021; Sharif et al., 2017; Solarin, 2014; Zhang & Zhang, 2021).

Tourism significantly contributes to the decline in Malaysia's environmental health (Ng et al., 2016). This is mainly due to the emission of $CO_2$ from various sources, including transportation, power generation, and heat production. Zaman et al. (2016) found a positive correlation between international tourism earnings and expenditures for travel products and increased $CO_2$ emissions in both developed and developing countries. There is a connection between tourism and $CO_2$ emissions through different transportation modes, the development of tourism facilities, and local and government services. Tsai et al. (2014) discovered a positive correlation between service levels in hotels and the average $CO_2$ emissions per guest. Furthermore, tourism has both biophysical and socio-cultural effects on the environment. Tourism contributes to air pollution through the release of smoke, sulfur dioxide, nitrogen oxides, and other hazardous chemicals. Tourist activities can negatively impact the natural environment and diminish its attractiveness. The introduction of waste can transform a picturesque location into a landfill. Mass tourism expansion has led to significant deforestation, which is a major global environmental concern. Tourism significantly contributes to noise pollution, encompassing both physical noise and vehicular traffic. Sustainable tourism is necessary to mitigate the negative impacts of tourism on society, the environment, the climate, and the economy.

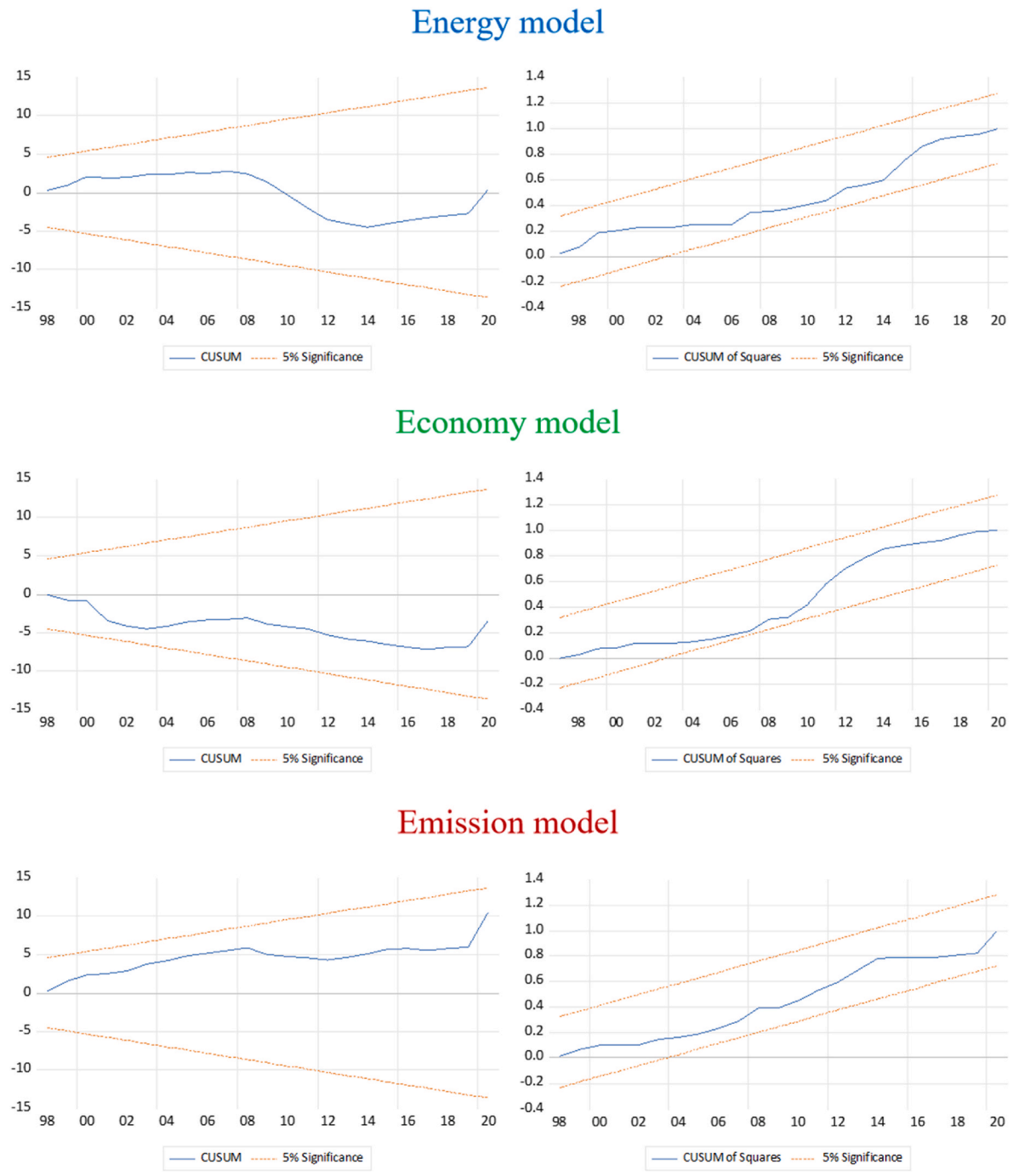


**Fig. 3.** The results of CUSUM and CUSUM of squares tests.

The study found a negative correlation between tourism receipts and carbon emissions, indicating that tourism receipts have the potential to reduce emissions in Malaysia. The results suggest that the tourism industry in Malaysia contributes to the improvement of environmental health. One potential explanation for this outcome is that tourism, being a significant part of the service sector, is relatively less energy-intensive or environmentally cleaner compared to the agricultural and industrial sectors. The findings of this study are consistent with Koçak et al. (2020), who observed that tourist arrivals have a positive impact on $CO_2$ emissions, while tourism receipts have a negative impact on $CO_2$ emissions in highly visited countries. Yıldırım et al. (2023) discovered a negative correlation between tourism receipts and carbon emissions in Mediterranean nations. An increase in tourism revenue may result in a greater emphasis on ecotourism, green tourism, and sustainable tourism. Tourism generates revenue that can be used to fund national parks, wildlife conservation, and the preservation of cultural heritage sites, as tourists visit pristine beaches, undisturbed forests, and scenic landscapes. The efforts lead to both negative impacts of tourism on carbon emissions and positive effects on environmental quality.

## 5. Conclusions and policy implications

### 5.1. Conclusions

Tourism contributes to economic growth through the generation of foreign currency and employment opportunities. Tourism contributes to

**Table 7**
The results of the robustness check.

| Variables | FMOLS | | DOLS | | CCR | |
|---|---|---|---|---|---|---|
| | Coefficient | t-Statistic | Coefficient | t-Statistic | Coefficient | t-Statistic |
| Energy model: dependent variable LEU | | | | | | |
| LTA | 0.4158** | 2.2018 | 0.4196** | 2.2103 | 0.4041** | 2.2921 |
| LTE | 0.4273*** | 4.7291 | 0.4422*** | 4.2288 | 0.4623*** | 4.0903 |
| LTR | 0.5459** | 2.3481 | 0.5491** | 2.7099 | 0.4730** | 2.6021 |
| C | 4.2683 | 1.7241 | 3.7863 | 1.8032 | 16.976 | 1.7455 |
| $R^2$ | 0.9731 | | 0.9682 | | 0.9782 | |
| Adjusted $R^2$ | 0.9375 | | 0.9302 | | 0.9450 | |
| Economy model: dependent variable LGDP | | | | | | |
| LTA | 0.4157** | 2.2689 | 0.4628** | 2.3786 | 0.4087** | 2.4463 |
| LTE | 0.4649*** | 9.5146 | 0.5062*** | 4.7588 | 0.4960*** | 5.9017 |
| LTR | 0.5181** | 2.2987 | 0.5545** | 2.4529 | 0.5287** | 2.4988 |
| C | 5.7292 | 1.7664 | 6.5486 | 1.6178 | 5.9058 | 1.6153 |
| $R^2$ | 0.9803 | | 0.9915 | | 0.9621 | |
| Adjusted $R^2$ | 0.9647 | | 0.9813 | | 0.9567 | |
| Emission model: dependent variable LCO2 | | | | | | |
| LTA | 0.3171*** | 6.5838 | 0.3161*** | 8.8499 | 0.3135*** | 5.5114 |
| LTE | 0.2252*** | 3.4255 | 0.2105*** | 5.0267 | 0.2210*** | 6.8772 |
| LTR | −0.0869*** | −5.0666 | −0.0817*** | −8.1153 | −0.0795*** | −6.9249 |
| C | 2.3307 | 1.4489 | 3.8103 | 1.8284 | 2.5484 | 1.9283 |
| $R^2$ | 0.9810 | | 0.9708 | | 0.9734 | |
| Adjusted $R^2$ | 0.9578 | | 0.9359 | | 0.9410 | |

Notes: LEU = Eenergy use, LGDP = Economic growth, LCO2 = $CO_2$ emissions, LTA = Tourist arrivals, LTE = Tourism expenditures, LTR = Tourism receipts, ***$p < 0.01$, **$p < 0.05$.

increased energy consumption through hotel accommodations and transportation. The utilization of energy in various tourism activities leads to an increase in carbon emissions. This study investigated the impact of tourism on Malaysia's energy consumption, economic development, and environmental sustainability. The time series data for Malaysia used in this analysis covers the period from 1995 to 2020. The stationarity of the series was assessed using the ADF, DF-GLS, and P-P unit root tests. The ARDL bounds test confirmed the presence of long-term cointegration. The ARDL estimation suggests that a 1 % increase in tourist arrivals, tourism expenditures, and tourism receipts would lead to a long-term increase in energy consumption of 0.46 %, 0.47 %, and 0.64 %, respectively. In the short term, the corresponding increases would be 0.30 %, 0.31 %, and 0.51 %. The study found that a 1 % increase in tourist arrivals, tourism expenditures, and tourism receipts would lead to a long-term increase in economic growth of 0.45 %, 0.47 %, and 0.54 %, respectively. In the short term, the corresponding increases would be 0.26 %, 0.32 %, and 0.40 %. The study's results suggest that a 1 % rise in tourist arrivals and tourism expenditures would lead to a long-term increase in carbon emissions of 0.32 % and 0.26 %, and a short-term increase of 0.39 % and 0.29 %, respectively. In addition, the findings suggest that a 1 % rise in tourism revenue would lead to a long-term reduction of 0.10 % in carbon emissions and a short-term reduction of 0.03 %. In addition, the ARDL results were verified using the FMOLS, DOLS, and CCR techniques. This study provides policy recommendations for sustainable tourism.

### *5.2. Policy implications*

Malaysia should implement policies to reduce the use of fossil fuels in the tourism industry, as there is a strong correlation between increased consumption of fossil fuel energy and carbon emissions. Effective legislation would promote tourism as a means of economic development, while also encouraging energy conservation, promoting renewable energy use, and protecting the environment. Policymakers may need to provide incentives to stakeholders in the tourism industry to encourage the adoption of renewable energy, carbon-neutral transportation, and emission-free technologies in order to promote sustainable tourism. Furthermore, the government may opt to fund eco-friendly public transportation, offer tax advantages, or provide incentives for taxpayers engaged in energy-efficient tourism services that utilize renewable energy resources. One possible approach to reducing dependence on cars and other fossil fuel-based transportation is to implement policies that promote bicycle-centric tourism. The government could demonstrate leadership by incorporating renewable energy technologies and energy-efficient elements into the infrastructure of popular tourist destinations. This would enable these locations to reduce their energy consumption costs. The utilization of energy-efficient practices and renewable energy sources not only reduces air pollution and carbon emissions, but also yields long-term financial savings for taxpayers and generates additional employment opportunities. The consumption of fossil fuel energy in hotels and restaurants should be limited to what is essential. Furthermore, there is potential to incentivize hotels and similar establishments to generate their own electricity through renewable sources. The Malaysian federal and state governments should collaborate to enhance the sustainability and environmental friendliness of the country's carbon-intensive tourism industry, aiming to reduce its negative impact on the environment.

Moreover, promoting technological innovation in the transportation sector is imperative, particularly through the adoption of energy-efficient vehicles and those powered by renewable energy sources. The growth of tourism can lead to a reduction in $CO_2$ emissions through investments in energy efficiency, renewable energy technologies, waste management, and the modernization of public transportation. In order to preserve the environment, the government may implement environmental levies in popular tourist destinations. The government may facilitate the adoption of environmentally friendly and low-carbon equipment, alternative energy sources for transport and logistics, and additional tourism-related events to reduce $CO_2$ emissions and prevent depletion of natural resources in the tourism industry. The potential reduction of emissions in Malaysia necessitates a reassessment of plans for tourism expansion and related industries. Examples of sustainable tourism that the administration should promote include ecotourism, educational tourism, cultural tourism, adventure tourism, and recreational tourism. Furthermore, promoting outdoor adventure activities such as scuba diving and hiking can help decrease energy consumption and mitigate environmental degradation. Moreover, implementing a carbon tax on the travel industry could serve as a means to promote low-carbon economic development. Additional options include investing in adequate monitoring and management equipment, implementing energy-saving light fixtures, installing environmentally-friendly air

conditioning systems, reducing water consumption, and utilizing cost-effective boilers for heating purposes.

Malaysia should implement policies to foster a carbon-neutral tourism sector due to its abundance of remarkable natural tourist attractions. Preserving Malaysia's natural environment is essential for attracting future tourists. Developing a sustainable tourism model would ensure the maintenance and enhancement of the environment, biodiversity, and ecosystems, thereby securing ongoing international tourist arrivals. The Malaysian government may introduce a system to hold tourists, residents, and other visitors responsible for their impact on the natural environment of the country's popular tourist attractions. The tourism sector should prioritize sustainability and environmental responsibility to enhance tourists' experiences and knowledge. In order to ensure the sustained effectiveness of an energy conservation campaign, individuals from diverse backgrounds, including tourists, can receive educational instruction. The public can be educated about the significance of energy conservation, environmental sustainability, and the adoption of green living, including during vacations, through the widespread dissemination of informational materials such as flyers and brochures, awareness campaigns featuring visually appealing infographics, and regular updates on the progress and initiatives of relevant authorities in promoting environmentally friendly practices.

Policymakers should prioritize the incorporation of energy- and tourism-related policies, particularly in their energy and environmental regulations and framework. Malaysia must enhance the competitiveness of its tourism industry to maximize its contribution to the country's GDP. This can be achieved by increasing revenue, establishing partnerships and attracting investments, and empowering local communities. It is crucial to ensure that these efforts do not have any adverse impacts on the domestic economy and the environment. Therefore, it is imperative to align the tourism sectors and their supply chain with the strategies outlined in the National Tourism Policy (NTP) in order to promote responsible consumption and environmentally friendly practices, in line with the SDGs. When all sectors of tourism and their supply chain activities align with and follow the NTP and SDGs strategies and practices, this industry can contribute to job creation, social integration, biodiversity conservation, sustainable livelihoods, improved human well-being, and the preservation of natural and cultural heritage. Malaysia could improve its current energy and environmental policies to address the issue of environmental degradation caused by increased fossil fuel usage in developing countries heavily reliant on tourism. There is a need for governments in the Southeast Asian region to collaborate in order to develop and implement effective strategies for sustainable tourism.

### 5.3. Limitations and future research directions

While the study's findings may have important implications for sustainable tourism policies, it also has some limitations. The research was constrained in its utilization of econometric methods due to the lack of available data on tourism indicators beyond the study's time period. Further research is needed to assess the effectiveness of regulations aimed at transitioning Malaysia's tourism sector to renewable energy sources. Additionally, the cost-effectiveness of constructing green-energy-designed tourism facilities in Malaysia to reduce overall energy consumption should be investigated. Additionally, additional research is required to identify the specific types of tourism that have the most significant influence on environmental quality, as well as the tourist destinations in Malaysia that are most vulnerable. Future research could investigate strategies for revitalizing tourism in Malaysia.

## CRediT authorship contribution statement

**Asif Raihan:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Syed Masiur Rahman:** Writing – review & editing, Visualization, Validation, Supervision, Investigation. **Tapan Sarker:** Writing – review & editing, Validation, Supervision, Investigation. **Mohammad Ridwan:** Writing – original draft, Validation, Software, Formal analysis, Data curation. **Malayaranjan Sahoo:** Writing – review & editing, Investigation. **Bablu Kumar Dhar:** Writing – review & editing. **Md Mustaqim Roshid:** Writing – review & editing, Investigation. **Samanta Islam:** Writing – review & editing, Investigation. **Grzegorz Zimon:** Writing – review & editing, Investigation. **ABM Mainul Bari:** Writing – review & editing, Investigation.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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