THE IMPACT OF CARBON EMISSIONS ON INTERNATIONAL TOURIST FLOWS IN SINGAPORE

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BY

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PREFACE

The motivation for engaging in this research study arises from the increasing global urgency to reconcile robust economic activities with environmental preservation. There is a significant need to empirically examine the unintended consequences of sector-specific growth, particularly in instances where the historical expansion of a vital economic pillar is tethered to energy-intensive infrastructure. While tourism is often viewed as a "clean" industry, its reliance on international connectivity and high-standard hospitality services poses a potential threat to long-term ecological sustainability if not managed within a carbon-efficient framework.

The selection of Singapore as the focal point of this study was prompted by the nation's dual identity as a premier global travel hub and a pioneer in sustainable urban planning. Despite proactive environmental policies, the statistical trends of the past three decades suggest a complex dependency between international visitor arrivals and carbon output. This project was undertaken to investigate that specific nexus, moving beyond theoretical frameworks to provide a data-driven analysis of how capital inflows and income growth influence the carbon intensity of the tourism sector.

The research was conducted using the **Autoregressive Distributed Lag (ARDL)** approach to ensure that both the long-run equilibrium and short-run dynamics of the economic landscape were accurately captured. This report serves as an effort to provide policymakers and academic stakeholders with a clearer understanding of the empirical relationship required for a sustainable economic transition in a modern city-state.

ABSTRACT

This study examines the long-run and short-run relationships, alongside the causal direction, between carbon dioxide emissions (CO2) and international tourist arrivals (TA) in Singapore from 1995 to 2024, while controlling for Gross Domestic Product (GDP) per capita and Foreign Direct Investment (FDI). Utilizing a quantitative time-series approach, the empirical framework relies on Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root testing, the Autoregressive Distributed Lag (ARDL) bounds test for cointegration, and the pairwise Granger causality test. To ensure the statistical reliability of the regression parameters, diagnostic tests for normality, heteroskedasticity, and serial correlation were also conducted.

The unit root test results indicate a mixed level of integration among the variables at (0) and (1), validating the application of the ARDL model. The ARDL bounds test confirms a stable long-run cointegrating relationship, as the calculated F-statistic of 4.2176 exceeds the upper critical bound of 3.67 at the 5% significance level. The long-run coefficient of CO2 is positive and statistically significant, revealing that a 1% increase in CO2 emissions is associated with a 7.1258% increase in TA on average. Conversely, FDI exhibits a significant negative long-run impact, where a 1% rise in FDI leads to a 3.29% decline in arrivals, suggesting industrial investment competition with tourism resources. Finally, the Granger causality test reveals a unidirectional causality flowing from TA to CO2 emissions, implying that tourist inflows drive energy consumption and carbon emissions rather than the other way around. These findings provide critical policy insights regarding the decarbonization of tourism infrastructure under the Singapore Green Plan 2030.

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LIST OF ABBREVIATIONS

ADF	Augmented Dicky-Fuller
ARDL	Autoregressive Distributed Lag
CO2	Carbon Dioxide Emissions
DOLS	Dynamic Ordinary Least Squares
EKC	Environmental Kuznets Curve
ELTH	Economics-Led Tourism Hypothesis
FDI	Foreign Direct Investment
GDP	Gross Domestic Product per capita
PP	Phillips-Perron
TA	Tourism Arrivals
TLGH	Tourism-Led Growth Hypothesis
UNWTO	United Nations World Tourism Organization
VECM	Vector Error Correction Model

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CHAPTER 1: RESEARCH OVERVIEW

1.1 Research Background

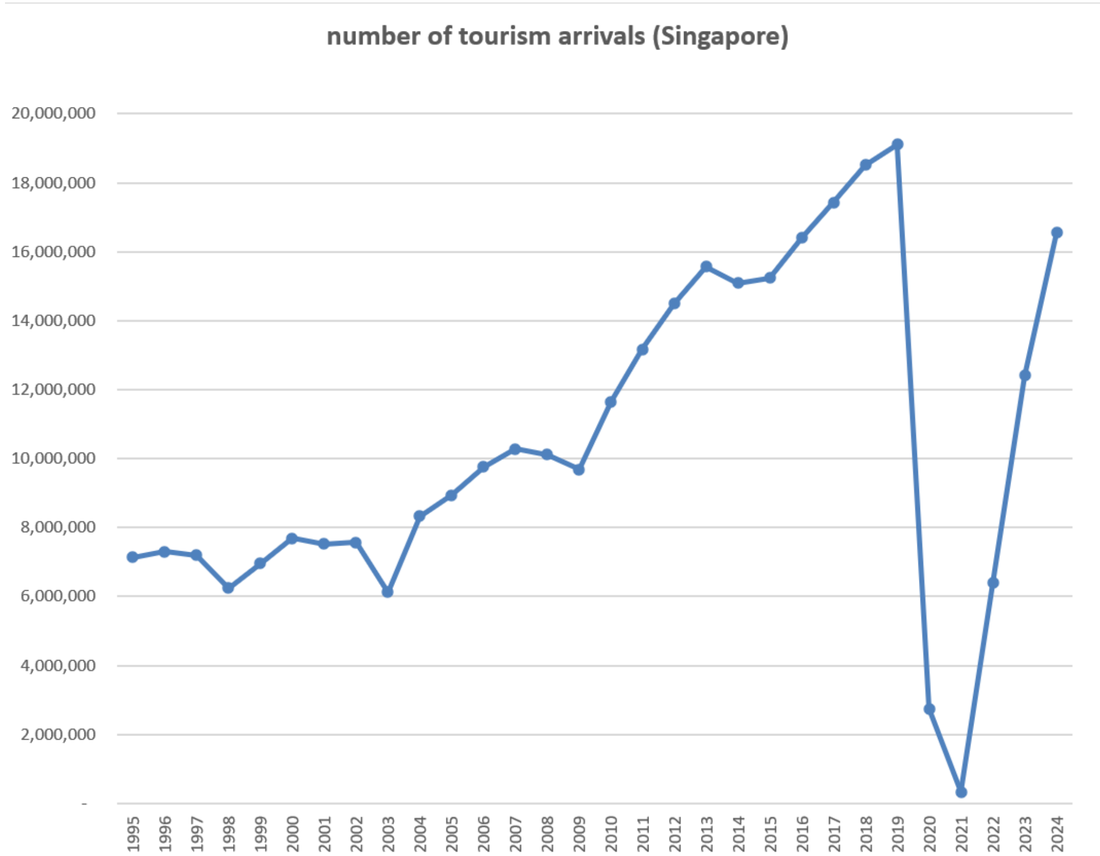
The nexus between environmental and economic factors has been a hot topic nowadays. This is due to the higher environmental degradation, which could be demonstrated by the rising CO2 (World Bank Open Data, 2025a). Since CO2 serves as the drivers that affect tourism development, it has become a concerning alarm that has raised the attention of all sectors, especially the tourism sector. The significance of the corresponding study has also been highlighted by the conflicting findings of literature reviews that examine the connection between environmental elements and tourism development. The increasing volume of economic activities leads to further degradation of the environment, which includes increasing CO2, as the increasing economic activities may rely on energy consumption from polluting sources. Moreover, the rising CO2 that degrades the environment lower the TA and earnings theoretically. However, the economic activities increase the tourism development as well. For instance, with an increase in a tourism destination's income, the destination's organization could reinvest the money back into the business and attract more tourists. In this case, the CO2 emissions could be understood as a side effect of the increasing economic activities that are difficult to eliminate.

In this regard, one relevant approach has been established by tourism as a key contributor to global economic growth, namely ecotourism. Tourism is defined as a social, cultural and economic situation of people moving to locations outside their usual environment for personal purposes. The tourism industry includes every establishment with its principal activity being tourism-related characteristic activity. It is the activities that create tourism-related characteristic products. Ecotourism is defined as a nature-based activity where visitors come to observe, gain knowledge, explore, experience, and cherish biological and cultural diversity with the responsible goal of preserving the ecosystem's integrity and improving the community's welfare. (UNWTO, 2025). As the number of environmentalists increases, the importance of studying the relationship between the tourism industry and environmental factors has become more crucial as well. Therefore, the concepts of ecotourism and sustainable tourism have become more widespread.

Singapore, as a developed country, strongly promotes ecotourism. By adopting environmentally sensitive policies, Singapore's tourism sector is expected to be believed will be sustainable and welcomed by residents. Furthermore, Singapore's enforced and appropriate laws commend environmental concern, such as the Singapore Productivity and Standards Board ISO 14000 Environmental and Management System Certification Scheme, which ensures businesses comply with environmental awareness requirements. Singapore has also been working to develop the nation as an entryway to other environmentally friendly tourist sites, such as Singapore's Orchid Gardens, because of its limited natural attractions. (Toh et al., 2001). Xu et al. (2017) employed the Total Relationship Flow Management Theorems (TRMFTs) in their research. It created the Exchange Information Requirements Guidance (EIR) framework, which helps the relevant parties comprehend, regulate, and manage the effects of ecotourism. By using this approach, managers, tourist developers, and policymakers may create effective and sustainable ecotourism. The outcomes of the numerous approaches of Singapore to strengthen its ecotourism may be indicated by the pattern of the number of TA and CO2.

Figure 1.1.1

Trend of TA in Singapore from 1995 to 2024

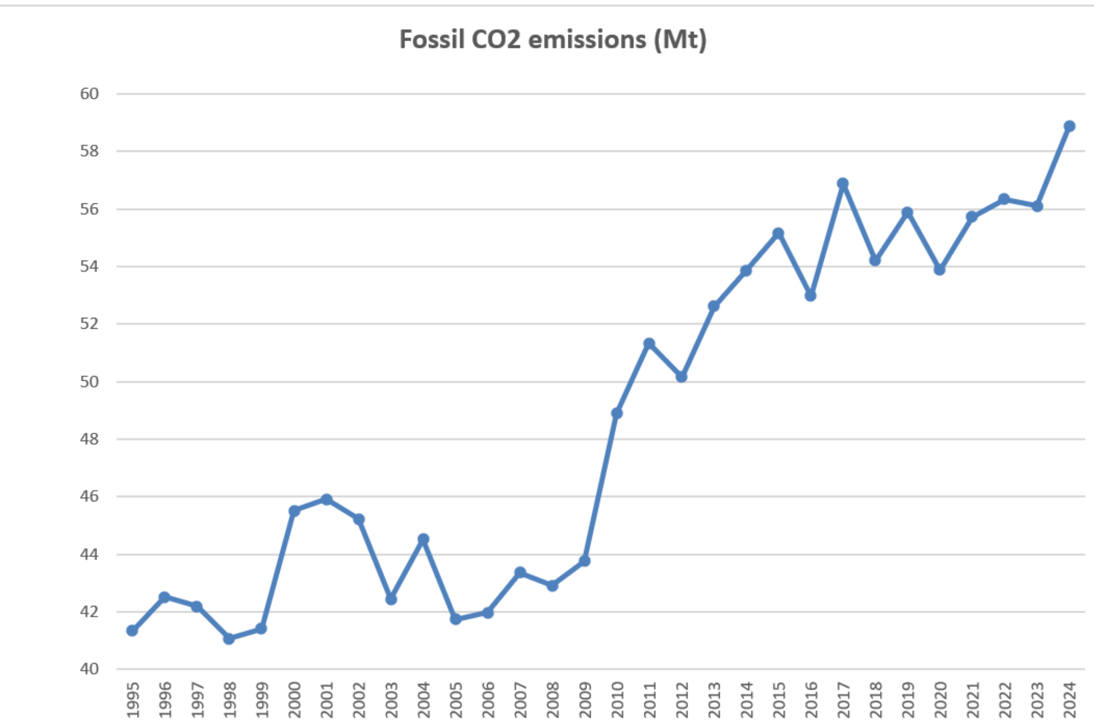


Source. International tourism: number of arrivals. Adapted from World Bank Open Data (2025)

As shown in Figure 1.1.1, Singapore's international TA from 1995 to 2024 have an upward-sloping trend. This increasing trend is attributed to several reasons, such as its ecotourism development and tourism policies. Ngoc et al. (2024) suggested that Singapore's well-aligned policies and investments contributed to its tourism development as well. Aside from the few minor reductions, there is an enormous reduction in the trend that was caused by the global pandemic, COVID-19 (Şanlıöz-özgen et al., 2025). Based on a study by Meng et al. (2012), the relatively minor reduction in international TA in Singapore in 1998 and 2009 is due to the global financial crisis and the 1997 Asian financial crisis. Another relatively smaller drop in 2003 was caused by the severe acute respiratory syndrome (SARS) pandemic. The most recent decline of the trend in the year 2014 was because of the aviation disaster, the disappearance of Malaysia Airlines' flight "MH370", which led to the fall of one of Singapore's largest tourism markets, Mainland China (Ramchandani, 2015). Singapore's trend of international TA is overall increasing, with its well-developed tourism policies and investment. The only three minor drops are caused by other factors that are hard to avoid, such as global pandemics and the global and Asian financial crisis. Despite these challenges, Singapore's tourism sector recovers quickly every time and continues to increase.

Figure 1.1.2

Trend of CO2 in Singapore from 1995 to 2024



Source. Total CO2 excluding Land Use, Land Use Change, and Forestry (LULUCF) (Metric tons). Adapted from World Bank Open Data (2025).

Figure 1.1.2 illustrates the trend of CO2 emissions in Singapore from 1995 to 2024; the trend is an overall uptrend despite the relatively minor fluctuations. Several factors contribute to this rising trend, including tourism and energy consumption. The study by

Hoa et al. (2024) applied the random effects model (REM) and the Cobb-Douglas framework to study six Asian developed countries: Singapore, Hong Kong, South Korea, China, Israel, and Japan. It reveals that a rise in power usage results in an increase in CO_2, indicating that the researched countries rely on electricity from polluting sources, such as CO_2, and Singapore is included. The study stated that the higher fossil fuel consumption, which generates energy for the six countries mentioned, increases the CO_2 as well. However, the increasing sustainable energy consumption contributes to the lowering in CO_2 of the countries mentioned, which shows that they are attempting to promote green energy as well (Xia et al., 2025). The energy consumption that relies on polluting sources causes the CO_2 to increase in Singapore, while the country's highly enforceable environmental policies lower the CO_2. The competition between energy consumption from green energy and polluting sources has caused fluctuation in Singapore's CO_2.

The trend in Singapore's FDI has shifted from traditional manufacturing toward high-value service sectors and digital infrastructure over the last two decades. While GDP has grown steadily, reaching over $80,000 in recent years, the growth rate slowed during the COVID-19 pandemic due to the cessation of international travel and logistics disruptions (Ministry of Trade and Industry [MTI], 2025). The subsequent rise in FDI inflows post-2022 can be attributed to the "Singapore Green Plan 2030," which redirected foreign capital into sustainable urban development and carbon-efficient transportation (MTI, 2025). This is a strategic move to decouple economic growth from environmental harm; however, the immediate effect of increased FDI and GDP is an expansion of energy-intensive services, which historically correlates with rising carbon emissions (Raihan & Tuspekova, 2022a). Consequently, the rising trend in these variables provides both the challenge of increased pollution and the economic resources to solve it.

As one of the solution approaches for the tourism and CO_2 paradox, Singapore emphasises its ecotourism. Singapore Green Plan (2025) highlights that Singapore positioned itself as the "City of Nature". It plans to build a sustainable environment for the local community as well as the tourists, in order to support the Sustainable Development Goals (SDGs).

There are a few tourism destinations built in Singapore that promote ecotourism. For example, the world-famous Gardens by the Bay and Bukit Timah Nature Reserve. These tourism destinations contribute to sustainable efforts as well. According to Gardens by the Bay (2025), Gardens by the Bay lowers solar heat gain, cools the specific zones, de-humidifies the air, and, most importantly, it generates energy and harnesses waste heat. Gardens by the Bay generates carbon-neutral electricity on-site and captures heat waste to regenerate liquid desiccant by utilising a Combined Heat Power (CHP) steam turbine, which is fuelled by wood and horticultural waste across Singapore. However, the understanding of Figure 1.1.2, the CO2 in Singapore, is yet to decrease overall. This indicates that there is space for improvement in Singapore's environmental policies, which includes its ecotourism. Therefore, this study, which fills the underexplored areas of study, provides a guideline to whom it may concern to better align with the relevant issues.

1.2 Research Problem

Singapore is a land-scarce country and is highly urbanised. Its characteristics have a vast difference from countries such as Thailand, which diversifies its tourism offerings through rural tourism and nature-based experiences. Singapore lacks large rural landscapes, thus limiting its capacity to develop and promote its own rural ecotourism as a counter against environmental degradation. In order for Singapore to mitigate the scarce land issue, it depends heavily on its urban infrastructure, man-made attractions and built environment to attract international tourists. This puts pressure on Singapore to maintain environmental quality and reduce its carbon footprint, as any deterioration in its domestic environment, such as air quality and urban livability, will directly affect tourist experiences. Singapore's rising CO2 and associated climate impacts pose an underlying challenge to its position as a clean and attractive tourism destination. Unlike countries like Thailand, which have the advantage of rural destinations that can disperse tourist activities across natural landscapes, Singapore must continue to adopt innovative urban sustainability measures to ensure its tourism competitiveness. One of the few viable pathways that Singapore should exercise is through the development, expansion and innovation of green infrastructure such as energy-efficient buildings, sustainable transport systems, and urban greening initiatives that can reduce emissions while enhancing the country's image as a sustainable destination (Tan et al., 2021). However, without stronger efforts to integrate sustainability into tourism development, Singapore will face risks such as reputational damage, reduced tourist satisfaction, and long-term declines in international tourist flows.

The rising trend of global environmental degradation, including the increasing CO2, is a growing concern. With CO2 being an undesirable side effect, the method to lower the environmental degradation has always been a troubling issue without perfect solutions yet. Developed countries like the US and Singapore, acting as role models, have been working on creating better solutions, including the inventions of various electric transportation, like electric bicycles and electric cars. However, the upward-trending CO2 of Singapore might be a signal of the strategy misalignment or space for improvement of its tourism sector. For example, according to the World Tourism Organization (2019), the overall TA emitted 1597 metric tons of carbon dioxide in 2016, with a growth of 25%, and the estimated CO2 were 1998 metric tons (Mt) of carbon dioxide. The global international TA in 2016 contributed 458 Mt and an estimated CO2 of 665 Mt, with a rate of 45% in 2030. In 2016, the domestic TA caused 912 Mt CO2 and an expected 1102 Mt CO2 in 2030, which is a growth of 21%. In the case of Singapore, a developed country, it has increasing TA and CO2 as well. Understanding the nexus between tourism and CO2 could assist in solving Singapore's increasing environmental problems.

As mentioned, Singapore has upward-sloping trends in both international TA and CO2 from 1995 to 2024. This indicates that despite Singapore's continuous efforts to solve the environmental problems, environmental degradation issues remain increasing. Furthermore, with the parallel relationships between Singapore's environmental degradation and its TA, it may reveal the possibility that Singapore's tourism industry might rely on polluting sources like CO2, which is supported by literature reviews. However, there is limited research that studies relevant topics in Singapore, such as conducting research with other approaches. Therefore, the clarification of the causal relationship between tourism and environmental degradation in Singapore must be further studied. This could assist in understanding the extent of environmental policies needed and outlining the strategies to solve Singapore's environmental problems and enhance its tourism development.

In summary, the critical issue is the lack of evidence that Singapore has moved past the peak of the Environmental Kuznets Curve (EKC) by Simon Kuznets, suggesting that environmental degradation initially rises with economic growth and then declines after the country reaches a certain level of income. While many nations hope economic growth eventually leads to better environmental quality, empirical evidence in Singapore suggests a long-term equilibrium where TA and CO2 move together (Katircioğlu, 2014). This is important because while Singapore promotes itself as a sustainable destination, its high-level urbanization and industrialization mean that tourism growth often necessitates increased energy consumption and pollution (Katircioğlu, 2014). If this nexus is not addressed, Singapore's tourism sector could become a primary driver of environmental degradation, contradicting its global sustainability commitments (Chen & Taylor, 2019).

1.3 Research Objectives

1. To examine the long-run and short-run relationship between carbon dioxide emissions (CO2) and international tourism arrivals (TA) in Singapore from 1995 to 2024, controlling for economic factors.
2. To identify the causal relationships between Singapore's carbon dioxide emissions (CO2) and tourism arrivals (TA), while controlling for the economic factors.

1.4 Research Questions

1. What is the long-run and short-run relationship between carbon dioxide emissions (CO_2) and international tourism arrivals (TA) in Singapore from 1995 to 2024, controlling for economic factors?
2. What are the causal relationships between Singapore's carbon dioxide emissions (CO_2) and tourism arrivals (TA) while controlling for the economic factors?

1.5 Research Significance

The result of this research on sustainable tourism development in Singapore holds significant value for addressing key challenges such as environmental conservation, economic viability, and community engagement for a range of stakeholders, including local businesses, tour operators, government bodies, and more. This research could provide practical insights that might influence changes in the tourism industry. There shall be examples for each group that will be outlined for beneficial parties, the significance of the study in their regard, and the suggested application model to best suit their situation.

Firstly, the understanding of CO_2 impact on the tourism industry is crucial to local businesses, which include hotels, resorts, restaurants, souvenir shops, and many other local entrepreneurs who rely on tourism revenue. The outcomes of this study provide a guideline for the local businesses to better align their strategy to mitigate the consequences of over-tourism. For instance, seasonal fluctuations and exhaustion of resources will threaten their long-term sustainability and profitability. These could benefit the businesses by adopting the recommended frameworks, such as waste reduction programs and community-based marketing, to enhance their competitiveness in the tourism market, foster customer loyalty, and contribute to the local economy.

Secondly, the tour operators, such as adventure guides, travel agencies, and excursion providers who design and deliver experiences for tourists, are concerned about the research learning as well. The research may provide significant value to them, since it provides data-driven evidence on balancing visitor satisfaction with ecological preservation, helping them to avoid risks that are linked with unsustainable practices. By obtaining the study's data and results, tour operators can discover new opportunities, collaborate with locals, and train their staff according to sustainable guidelines. This can lead to higher ratings, repeat business, and meet the standards of the Global Sustainable Tourism Council (GSTC, 2025).

Thirdly, the research could be crucial for Singapore's government bodies, and the local authorities, environmental agencies, and tourism ministries are included, which aim for regional development. The research provides an empirical analysis of the interplay between tourism and environmental health, which illustrates the connection between tourism growth with the environment. Some policies focus only on short-term benefits and miss long-term problems like damage to nature or pressure on local infrastructure, and by showing the importance of sustainable tourism in job creation and boosting the local economy, the research provides solid evidence for smarter planning. Governments can benefit from the research outcome by zoning laws or incentives for ecotourism that balance economic growth and the environment. Furthermore, this can help achieve Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action) and SDG 8 (Decent Work and Economic Growth) (United Nations, 2025).

Fourthly, the research could be valuable to scholars and researchers who study tourism, environmental science, or sustainable development. This is due to the fact that the causality relationship between tourism and environmental factors is essential for further study and policymaking in the economy. The rising CO2, which indicate the low air quality in the tourism destinations, repel tourists, while the development of economic activities attracts tourists, even though it comes with the side effect of increasing CO2. In this case, with better knowledge of the economy's situation, the parties concerned could better address strategies that are more suitable for the situation. In addition, the research might contribute to the academic discourse by providing empirical data and frameworks that might be significant for future reference. The results could be utilised by outlining new studies or working with institutions, government bodies, and businesses to test and refine sustainable tourism models.

CHAPTER 2: LITERATURE REVIEW

2.1 Underlying theories

2.1.1 Economic-Led Tourism Hypothesis (ELTH)

The diverse results of the studies of the causality relationship between tourism development and economic growth have led to the establishment of different theories and hypotheses. According to the Economic-Led Tourism Hypothesis (ELTH), investments in infrastructure and human resources, well-defined and enforced property rights, and stable political institutions might all contribute to economic growth. Subsequently, this growth will drive tourism development and serve as a signal to a country's foreign visitors. This indicates that a country's tourism development can be affected by its economic status. For instance, Payne & Mervar (2010)'s research studies the Croatian economy and stated that its government should promote the overall economic growth for the tourism industry to benefit from the prosperity of the economy. However, the Tourism-Led Growth Hypothesis (TLGH) asserts that tourism development and economic growth have a guaranteed positive relationship. It suggests that the spill-over effect of tourism industry studies on the causality relationship between tourism development and economic growth prosperity benefits the economic growth (Perles-Ribes et al., 2017). For example, Oh (2005)'s study found that the Korean economy supports the ELTH while rejecting the TLGH.

By applying a suitable hypothesis, a country with a suitable economic situation could adjust its policy accordingly. This study emphasises the ELTH, which aims to study the economic factors that influence tourism development. Multiple indicators of tourism development and economic growth will be measured to examine the validity of the ELTH in the economy studied, whether the causality relationship of the economy is tourism development being influenced by economic growth. In this study, GDP per capita and FDI will be the economic variables of Singapore from 1995 to 2024 that influence the economy's TA directly and economically, which is proven by the hypothesis. These two variables will be measured to learn the causality relationship between the economy's tourism industry and economic factors. By implementing the ELTH in this research, Increased GDP per capita and FDI will result in more tourists arriving.

2.1.2 Environmental Kuznets Curve (EKC)

The Environmental Kuznets Curve (EKC) hypothesis, first proposed by Grossman & Krueger (1995), describes an inverted U-shaped relationship between environmental degradation and economic growth. According to the EKC, environmental degradation, which is commonly measured by CO2, initially increases simultaneously with rising national income because of the scale effect of industrial expansion and higher consumption of energy. However, more growth in the economy causes environmental degradation to decrease when a specific income level is achieved. This downward slope occurs because of the composition effect, which society prefers fewer polluting industries and the technique effect, which firms adopt cleaner technologies and are restricted by environmental regulations.

EKC framework has been applied by empirical studies to examine the nexus between economic growth, CO2, and tourism development. For example, Nosheen et al. (2020) verified that the EKC hypothesis was valid in Asian economies between 1995 and 2017, finding that tourism significantly contributes to environmental degradation in the early stages of growth, but it can be mitigated once higher income levels enable sustainable practices. With a similar result, Katircioğlu (2014) specifically tested the tourism-induced EKC hypothesis in Singapore and established a long-run equilibrium relationship between tourism development and CO2, confirming that growth initially increases CO2 but may eventually reverse and support environmental improvement at higher income levels.

This study applies the EKC hypothesis to explain the role of economic factors in the relationship between CO2 and international TA in Singapore. By including GDP and FDI as control variables, the EKC framework justifies examining whether Singapore, which is already a high-income developed economy, has reached the turning point and thereby support its sustainable tourism development. The observed simultaneous upward trends in both CO2 and TA in Singapore from 1995 to 2024 (as shown in Figures 1.1.1 and 1.1.2) suggest that the country may still be operating on the upward slope of the EKC, or stronger policy interventions are required to have a transition to the downward phase. Therefore, the EKC theory provides a robust foundation for this research to investigate whether economic growth eventually mitigates the environmental pressure on Singapore's tourism sector or whether additional sustainability measures are needed to align with tourists' growing preference for low-carbon destinations.

2.2 Review of variables

There have been various studies that examine the relationship between TA and economic growth. This study brings out environmental and macroeconomic indicators that examine their relationship and employ a multivariate framework. This examines the dynamic interplay between the dependent variable, Tourism arrival (TA), and the set of independent variables, Carbon Dioxide Emission (CO2), Foreign Direct Investment (FDI), and Gross Domestic Product per capita (GDP).

2.2.1 Carbon Dioxide Emission (CO2)

The increase in economic growth and infrastructure development, such as industrialisation and infrastructure improvements, could indirectly lead to an increase in CO2, which are both critical drivers of tourism, due to more friendly accessibility and appealing destinations, thus leading to higher international TA. For instance, elevated CO2 levels from energy consumption and capital investment in emerging economies support the expansion of tourism facilities, which in turn foster a greater visitor inflow in the long run (Khan et al., 2020). For a similar example, bidirectional relationships reveal a positive correlation where rising CO2, tied to economic dynamism, coincide with and contribute to increased TA, particularly in developing contexts in diverse country groups like BRICS and

CIVETS (Ghosh et al., 2024). Overall, this dynamic underscores CO_2 as an indirect enabler of tourism through growth-related mechanisms.

Furthermore, the research on CO_2 is significant for several reasons. For example, according to the World Bank Open Data (2025d), the current health expenditure per capita (current USD) has a rising trend as well. The degradation of the environment, including CO_2, could be considered one of the main contributors. The research study done by Humssi et al. (2025) utilised the quantile regression analysis at 20 levels (percentiles) to study 166 countries relationship between CO_2, GDP, and healthcare expenditure. The result indicates that increases in CO_2 and GDP are associated with an increase in healthcare cost per capita in absolute units for developed countries, which is a significant issue to be addressed.

This research studies the relationship between TA and CO_2, and some empirical studies reveal that TA and CO_2 have complex, frequently bidirectional relationships, with increases in CO_2 having a positive influence on TA, vice versa, especially in industrialised and emerging nations. For example, an empirical review unveils that Singapore's tourism industry is relying on CO_2. The research conducted the Dynamic Ordinary Least Squares (DOLS) and found that a 1% growth of Singapore's tourism industry comes along with a 0.45% growth in its CO_2 (Raihan & Tuspekova, 2022b). By using panel data from 30 Chinese provinces over the years from 1998 to 2017, research that employed Granger causality tests demonstrates bidirectional causality between CO_2 and domestic TA. It indicates that rising emissions stemming from economic activities could enhance tourism flows by supporting infrastructure and attractiveness (Zikirya et al., 2021). Another example is from (Ben Jebli et al., 2019), which points out that in a vector error correction model (VECM) analysis of OECD countries from 1995 to 2014, long-run bidirectional causality is observed between CO_2 and international TA. It points out that higher emissions, as indicators of energy-driven growth, foster tourism expansion through improved economic integration and FDI. Time-frequency analyses further support this positive linkage in diverse economies, which is an example where wavelet coherence reveals bidirectional interactions between CO2 and Tourism, implying that emission surges during industrial peaks could drive tourism increases by boosting connectivity and visitor appeal in the short to medium term (Aslan et al., 2024). In the other case that studies Turkey, ARDL bounds testing and Granger causality on long-run data uncover bidirectional causality, where CO2 positively correlate with TA by enabling energy-intensive development that enhances tourism infrastructure and openness (Ozturk & Acaravci, 2013). In addition, Panel ARDL models applied to European Union data from 1995 to 2019 also confirm bidirectional causality, showing that CO2 increases could lead to higher TA in the long run by intertwining with trade openness and energy intensity, though this may pose sustainability challenges (Meșter et al., 2023).

However, there is a limited body of research examining the extent to which CO2 drive TA, as the majority of existing studies focus on the reverse relationship, which is how tourism activity contributes to CO2. The former perspective, which is the focus of this study, remains comparatively underexplored. For instance, most studies on CO2 and tourism are like Gössling et al. (2022), which examines how the tourism sector contributes to greenhouse gas emissions, particularly CO2, which is the opposite of the causation relationship of this study. Collectively, these findings underscore that while CO2 often proxy for economic vitality that propels TA, the relationship warrants policy interventions to mitigate environmental impacts, especially in samples like Singapore from 1995 to 2024, where rapid growth has amplified both variables.

2.2.2 Gross Domestic Product per capita (GDP)

GDP has been proven to have a positive relationship with tourism development as tourism expenditures could contribute to the economy's GDP, and the contributions could be reinvested in the development of the tourism industry as well. Empirical studies conducted to learn about the causal relationship between tourism and economic growth also utilise GDP as a macroeconomic determinant and find that it is one of the critical factors. For instance, a panel analysis of 218 countries' GDP per capita from 1995 to 2012 was done by Martins et al. (2017) to determine the relationship between tourism demand and macroeconomic variables. Research found that the world's increasing GDP per capita helps boost the TA, ceteris paribus. Financial variables and economic variables were used in time-series research as the independent variables of tourism development. The research found that the GDP of Malaysia from 1975 to 2013 increased tourism both directly and indirectly through financial development (Shahbaz et al., 2015). Another research done confirmed the role of GDP per capita in boosting tourism development by reviewing over 87 studies, with mixed results of the causal relationship between tourism development and economic factors. The research conducted time-series, panel, and cross-sectional analyses of 179 countries from 1952 to 2012 to learn the positive relationships between tourism development and economic variables. 83 out of the 87 studies utilise GDP as one of the variables, which reinforces the significance of GDP's role in the study of this causal relationship with tourism development (Del P Pablo-Romero & Molina, 2013). Katircioglu (2008) did research on Cyprus's tourism and economic factors. The tests include the bounds test for co-integration and the Granger causality tests, which found that real GDP boosts international trade and TA, and international trade alone stimulates international TA. The causality relationship between tourism and GDP from Sichuan, China, is studied as well. The research was done with the stability test of the Vector Auto-Regression (VAR) Model, variance decomposition analysis, and Impulse Response Functions (IRF). The expansion of Sichuan, China's tourism development by GDP is more significant than the growth of its GDP by tourism development from 1990 to 2009. Furthermore, the impact of its GDP on tourism grows as time goes on (He & Zheng, 2011). The empirical studies done found unidirectional (tourism-led-growth or growth-led-tourism) and bidirectional relationships between GDP and tourism variables. Such as Cortés-Jiménez et al.'s (2011) study, which learns about Tunisia's case over the period 1975 to 2002. Although the authors intended to conduct research on tourism, leading to growth, they found that the case has an economic-led tourism. The results could be diverse besides those two relationships as well. Tanzania results show short-term bidirectional causality between tourism and economic factors, and long-term unidirectional causality from economic factors to tourism development (Odhiambo, 2011).

2.2.3 Foreign Direct Investment (FDI)

The Empirical studies found that FDI and tourism development have mixed results on their causal relationships. The FDI in the tourism sector may be utilised to enhance the tourism destination's facilities, while business tourism is able to attract FDI. For example, Haley and Haley (1997) and Alam et al. (2015) prove that tourism drives FDI of a country. This suggests that the government may encourage tourists to spend more. Haley and Haley's (1997) research reviewed Vietnam from 1988 to 1995 and suggested that the policy should encourage tourists to spend more. Nevertheless, numerous studies come out with the results of FDI being a factor in tourism development. Nunkoo & Seetanah's (2017) research conducted several tests, such as the Unit Root test, Granger Causality Test, and VECM, on Mauritius from 1984 to 2014. The findings demonstrated both the short-term dynamic interplay between FDI and tourism development and the long-term positive impacts of FDI on tourism. According to Othman et al. (2012), FDI and tourism development of 18 tourism destinations, including Malaysia, Singapore, and more, were researched. The researchers used the ARDL approach and the Granger Causality Test. They confirmed the long-run relationship between tourism and FDI and found a bidirectional causality relationship between the variables. The results stated that FDI Granger-caused tourism development, as well as tourism development Granger-caused FDI in the long run. However, in the short run, similar bidirectional causality is observed as well. Next, Panel co-integration tests for the developing countries from 1995 to 2008 show that tourism-related FDI and tourism growth are co-integrated in the long run. The bilateral long-run causality between tourism-related FDI and tourism development is found in the Granger Causality in the VECM framework as well. This indicates that short-run adjustments will occur to restore the long-run equilibrium of the variables in the case of a shock incident in the system. After getting the results by studying FDI and tourism development, the authors suggest the relevant "soft" and "hard" policies to be implemented in the developing countries (Samimi et al., 2013). The bounds testing was employed and confirms the cointegration of FDI and tourism earnings as well, according to Jayaraman et al. (2013). The test found a positive relationship between tourism revenues and FDI. A 10% of FDI to GDP leads to a rise in tourism revenue of approximately 0.49%. Therefore, the authors suggested the government promote FDI in tourism-related activities. There was another study done by Faisal et al. (2021) that emphasises the importance of the effects of FDI, tourism and oil prices on the GDP for Turkey. The researchers conducted a symmetric causality test and found that the positive component of FDI caused the positive components of GDP, tourism and oil. They employed Fully Modified Ordinary Least Squares (FMOLS) and DOLS, and both found a positive and statistically significant effect of FDI on tourism development. The study highlights how crucial FDI is in the case of Turkey's tourism industry.

2.3 Literature Gap

Although there is a lot of research that estimates tourism carbon footprint across nations, it needs to be addressed that the impact of rising CO2 on international TA remains underexplored in the research world, as Anser et al. (2020) mentioned. While numerous studies address the environmental consequences of climate change, such as global temperature rise and changing weather events, there are limited studies that specifically investigate how increasing CO2 levels influence tourism patterns. Tourism is a critical economic driver for many countries, including Singapore. Their economic status may be influenced by TA. This gap is significant, and without targeted research into how CO2 affect tourism factors, such as destination choices, travel behaviours, and tourist perceptions, there will be a lack of evidence to adopt strategies effectively by policymakers and industry stakeholders. The gap includes using ARDL to study Singapore's carbon dioxide emissions, leading to its tourism development. By understanding these dynamics, they could anticipate shifts in TA and mitigate potential declines driven by environmental concerns.

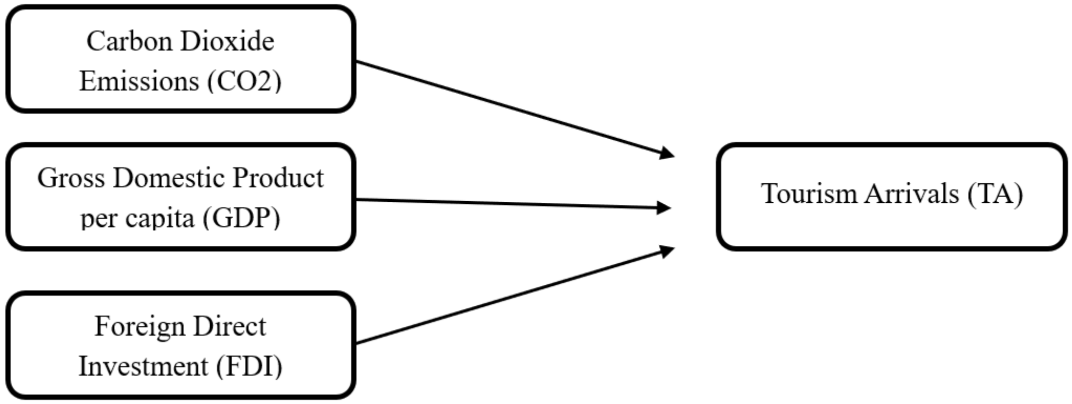
Other than that, without research into the specific impact of CO2 on tourism, there might be a gap in understanding how environmental degradation shapes tourist behaviour, as mentioned by Juvan & Dolnicar (2024). In their study, they mention that environmentally conscious tourists are an increasing demographic due to the global awareness of climate change is also growing, and it results in global tourists increasingly factoring sustainability into their travel decisions. For example, empirical reviews of relevant research, such as Ghosh et al.'s (2024) study, reveal that the two variables mentioned have a bidirectional relationship. Another past research example by Chowdhury et al. (2024) shows that the growth of the economy's tourism industry leads to an increase in its CO2 in Eastern African countries. These mixed result of similar studies on different regions indicates that different tourism destinations have different conditions regarding their economic and environmental aspects. It is unclear how perceptions of high CO2 or related environmental degradation influence destination choices, travel behaviours, and tourist perceptions without comprehensive studies, to the best of our knowledge. However, the findings of each economy are essential for various parties and the research on the relevant topics by using Singapore as a sample is insufficient and limited. This gap in knowledge greatly hinders the ability of policymakers and industry stakeholders to predict tourist behaviours and could only passively respond based on the situation, leaving destinations, especially for countries like Singapore, with increasing CO2 and TA, further unprepared to shift towards more sustainable travel preferences. Conducting research in this area could provide a guideline and a clear view of Singapore's situation, revealing opportunities to align tourism offerings for tourists who are environmentally conscious.

Furthermore, Aliyah et al. (2025) mention that practising green boosts and plays a significant role in customer satisfaction in their study. Failing to investigate the relationship between CO2 and tourism could result in Singapore missing out on the potential for economic growth of its sustainable tourism market. Environmentally conscious tourists are a segment of tourism consumers that is continuously growing; they seek destinations and experiences that are preferably low-carbon practices. Without factual data for policymakers and industry stakeholders to guide them in developing sustainable tourism initiatives, Singapore might lose its competitiveness to other tourism destinations that proactively cater to this market. By addressing this research gap, Singapore could position itself as a pioneer in sustainable tourism and attract high-value tourists. This secures long-term economic benefits from a sector that is shaped by environmental considerations.

2.4 Conceptual Framework

Figure 2.4

Proposed Conceptual Framework



The conceptual framework acts as a guide for researchers to organise ideas, variables and the relationship between the variables to guide a study. It explains how different elements interact with each other, synthesised with theories and empirical evidence. Figure 2.4 illustrates this research on Tourism Arrivals (TA), which acts as the dependent variable, having Carbon Dioxide Emission (CO2), Foreign Direct Investment (FDI), and Gross Domestic Product per capita (GDP) as independent variables. The objective of this conceptual framework is to find out how these independent variables influence the dependent variable, TA.

2.5 Hypothesis Development

For the hypothesis development, the expected outcomes are established to study the relationships between the variables. The hypothesis development for this study is to learn about the impact of carbon dioxide emissions (CO2), Gross Domestic Product per capita (GDP), and Foreign Direct Investment (FDI) on International Tourist Arrivals (TA) in Singapore from 1995 to 2024. These anticipations are formulated to examine the expected interactions between selected variables.

2.5.1 Carbon Dioxide Emission (CO2)

H_0: There is no significant relationship between Carbon Dioxide Emission (CO2) and Tourism Arrivals (TA).

H_1: There is a significant relationship between Carbon Dioxide Emission (CO2) and Tourism Arrivals (TA).

2.5.2 Gross Domestic Product per capita (GDP)

H_2: There is no significant relationship between Gross Domestic Product per capita (GDP) and Tourism Arrivals (TA).

H_3: There is a significant relationship between Gross Domestic Product per capita (GDP) and Tourism Arrivals (TA).

2.5.3 Foreign Direct Investment (FDI)

H_4: There is no significant relationship between Foreign Direct Investment (FDI) and Tourism Arrivals (TA).

H_5: There is a significant relationship between Foreign Direct Investment (FDI) and Tourism Arrivals (TA).

CHAPTER 3: METHODOLOGY

3.1 Research Design

Research Design is the plan of steps that the researchers follow to achieve the research objective and answer research questions validly. It confirms the type of analysis for the desired results. A good research design enables the researchers to obtain the answers to the research questions. It develops logical and systematic guidelines for researchers to conduct their studies. A research design includes the research's blueprint of data collection, measurement and analysis. For example, there are studies designed for both qualitative and quantitative data, and categories of designs like experimental research design (Khanday & Khanam, 2023).

This research applied a quantitative approach to study the relationships between Singapore's TA and CO2, while GDP per capita and FDI served as the control variables. The sample size is from 1995 to 2024. By quantifying each variable, the time series data of Singapore from 1995 to 2024 are collected. The environmental degradations are measured by utilising the CO2 in the unit of tons as an indicator. GDP per capita and FDI are the proxies of the economic variables in the research. The TA indicate the tourism development of Singapore in the research study. The time series data were utilised to conduct econometric analyses, including the Autoregressive Distributed Lag (ARDL) model. By adopting such methods, the results allowed identification of long-run and short-run dynamics among the variables. In order to identify the relationship between the variables, causal research is conducted. Causal research is essential in learning the effectiveness of policies, programs, and interventions. By learning the outcome of causal research, policymakers and researchers are able to better employ genuinely useful strategies (Steiner & Kim, 2024).

3.2 Model Specification

$$\log TA_t = \alpha + \beta_1 \log CO2_t + \beta_2 \log GDP_t + \beta_3 \log FDI_t + \varepsilon_t$$

t represents the years (t = 1995, 1996, ..., 2024)

TA= Tourism Arrivals of Singapore (Number of tourists)

$CO2$ = Carbon Dioxide Emissions of Singapore (Metric tons)

GDP= GDP per capita of Singapore (constant USD)

FDI= FDI, net inflows of Singapore (% of GDP)

Our research adopts a double-log (log-log) model specification for both dependent (TA) and independent variables (CO2, GDP, and FDI). The variables are expressed in their natural logarithmic form. Applying the double-log model is considered more suitable for this research for several reasons. The first reason is contributed by the estimated coefficients being able to be interpreted directly as elasticities, meaning they capture the percentage change in TA associated with a one percent change in each explanatory variable. This approach is particularly useful in tourism and economic research, where relative changes are more meaningful than absolute changes. Secondly, when the data is transformed into logarithmic form, it helps to linearise potentially nonlinear relationships, as many economic variables are related in multiplicative rather than additive ways. Thirdly, applying the double-log model helps to mitigate issues such as heteroskedasticity, multicollinearity, and skewness in the data, since variables such as GDP, FDI, and TA often exhibit exponential growth trends and wide variation in scale. At last, the double-log model converts all variables into the same scale of proportion. This enhances the model's comparability of coefficients across variables measured in different units. Overall, the double-log model provides a more reliable and interpretable framework for examining the relationship between carbon emissions and international tourist flows in Singapore.

Whereas the ARDL model that analyses the short-run and long-run relationship between the variables could be denoted as:

$$log(TA_t) = \alpha_0 + \sum_{i=1}^{p} \phi_i \, log(TA_{t-i}) + \sum_{j=0}^{q_1} \beta_j \, log(CO2_{t-j}) + \sum_{k=0}^{q_2} \gamma_k \, log(GDP_{t-k}) + \sum_{l=0}^{q_3} \delta_l \, log(FDI_{t-l}) + \varepsilon_t$$

Where $p, q_1, q_2, and\ q_3$ are denoted as the lag lengths.

The justification for adopting the ARDL framework rests on its ability to address several econometric challenges inherent in tourism and environmental research. The model is suitable for variables with mixed orders of integration, effectively accommodating a combination of I (0) and I (1) series (Pesaran et al., 2001). This ensures that the model does not require all variables to be stationary at the same level, simplifying the estimation process while maintaining academic rigor (Dogan & Aslan, 2017). Moreover, the ARDL model is specifically recognized for being highly efficient for smaller datasets; it provides statistically significant results in finite samples where the Johansen cointegration technique might suffer from power loss or biased estimates (Ghatak & Siddiki, 2001). Additionally, the model utilizes a flexible lag structure to capture the specific timing of impacts across different variables. This makes the ARDL approach exceptionally efficient in estimating long and short-run relationships simultaneously, providing a comprehensive and reliable view of the tourism-emissions nexus (Song et al., 2019).

3.3 Data Collections Method

Secondary data are chosen for this research as the data collection method from established and reliable sources. Secondary data refers to information that has already been collected and published by institutions for multiple purposes, such as academic reporting, policy making or analysis, and economic monitoring (EBSCO, 2025). The decision to use secondary data is based on both the nature of the research topic and practical considerations. For this research, all secondary data is obtained from the World Bank.

3.4 Data Descriptions

Table 3.4

Data Sources and Proxy of Variables

Acronym	Variables	Proxy	Data Sources
TA	Tourism Arrivals	International tourism, number of arrivals	World Bank Open Data (2025b)
CO2	Carbon Dioxide Emissions	Carbon dioxide emissions (CO2) (total) excluding LULUCF (Mt Co2e)	World Bank Open Data (2025c)
GDP	Gross Domestic Product per capita	GDP per capita (constant 2015 USD)	World Bank Open Data (2025e)
FDI	Foreign Direct Investment	FDI, net inflows (% of GDP)	World Bank Open Data (2025f)

Tourism arrivals (TA), being the only dependent variable of this study, are proxied by the number of international TA. It represents the total number of international tourists who engage in tourism-related activities for personal purposes by entering another country, which in this case is Singapore, within a given year. This indicator is widely used in tourism economics research as a measure of tourism demand and industry performance. Higher TA reflect stronger international interest, increased foreign exchange earnings, and growth in the tourism sector (Databank, 2025a).

Carbon Dioxide Emissions (CO2) serve as an indicator of environmental degradation. It is measured as total CO2 excluding Land Use, Land Use Change and Forestry (LULUCF). It is one of the main variables of this study, as this study investigates its impact on the tourism industry in Singapore from 1995 to 2024. The data of this variable is measured by the annual emissions of carbon dioxide, which is one of the Kyoto greenhouse gases from various industries. The measure is standardised utilising Global Warming Potential (GWP) factors to IPCC's 5^{th} Assessment Report (AR5) (Databank, 2025b).

Gross Domestic Product per capita (GDP) represents the total monetary value of all goods and services produced within a country's economic territory during a specified accounting period, divided by its total population to achieve a per capita estimate. It reflects the overall economic activity and income generated from production. GDP can be calculated through three approaches, which include the expenditure method, the income method, and the production method. For comparability across countries, this indicator is typically reported in current U.S. dollars (Databank, 2025c).

Lastly, Foreign Direct Investment (FDI), which is measured by FDI, net inflows (% of GDP), which means it is measured in percentage of the country's Gross Domestic Product. FDI includes equity investment, and investment in indirectly affected or managed enterprises, investment in fellow enterprises, debt, and reverse investment (International

Monetary Fund, 2010). It is a type of cross-border investment that represents the flow of direct investment equity by totalling up equity capital, reinvestment of earnings, and other capital. This indicator includes elements like greenfield investment and more (Databank, 2025d).

3.5 Sampling Design

The sample design includes details of the sample chosen. In this study, the samples selected are data from countries over time periods. As mentioned, the literature reviews, such as Ghosh et al.'s (2024) and Chowdhury et al.'s (2024) studies, show mixed results, which unveil the high possibility that different economies have different conditions, which require different strategies, regarding the causal relationship between tourism and environmental factors. Therefore, by employing time series data, there is only one sample country studied, which is Singapore, and the sample periods are from 1995 to 2024. With the results specifically studied from the case of Singapore, it could better align the strategies to improve its economy.

3.6 Proposed Data Analysis Tool

3.6.1 Unit Root Test

Unit root test, also known as the stationary test, is employed to examine the stationarity properties of time series data. Applying the unit root test ensures the validity of the regression model by confirming that the time series variables are either stationary in levels or become stationary after differencing. This step is essential to avoid spurious results and to establish reliable long-run and short-run relationships among the variables (Gujarati & D. N., 2009). Two of the most common tests include the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test. The test will be conducted in EViews.

3.6.1.1 Augmented Dickey-Fuller (ADF) test

The Augmented Dickey-Fuller (ADF) test incorporates lagged differences of the dependent variable to control for higher-order autocorrelation. If the test statistic is more negative than the critical value, the null hypothesis is rejected, indicating that the series is stationary. The test could be conducted by utilising the test statistic approach. The test statistic could be obtained from EViews or calculated by using the formula:

$$t_{\hat{\beta}_i} = \frac{\hat{\beta}_i}{SE(\hat{\beta}_i)}$$

The hypotheses are developed as below:

H_0: The series is not stationary.

H_1: The series is stationary.

If the p-value is greater than the significance level (0.05) or the test statistic value is smaller than the critical value from the t-distribution, it indicates that H0 is not rejected, which shows no stationary issue in the model.

3.6.1.2 Phillips–Perron (PP) test

The Phillips–Perron (PP) test also tests for a unit root, but it adjusts for autocorrelation and heteroskedasticity in the error terms using non-parametric methods rather than including lagged differences. This makes the PP test more robust in certain situations where the ADF may not adequately capture autocorrelation. Both the ADF and PP tests would be conducted on EViews to ensure the validity of the results. The test could be conducted on both test statistic approach and p-value approach.

The hypotheses are listed below:

H_0: The series is not stationary.
H_1: The series is stationary.
In the case of the p-value being larger than the significance level (0.05) or the test statistic being less than the critical value from the t-distribution, it shows no stationary issue in the model.

3.6.2 Autoregressive Distributed Lag

The Autoregressive Distributed Lag (ARDL) model is a model that analyses both short-run dynamics and long-run relationships between variables. The ARDL model was developed by Pesaran, Shin, and Smith (2001), and it helps to determine whether a long-run equilibrium relationship exists among variables. Including the bounds test for cointegration can help determine whether a stable long-run equilibrium exists among the variables. The test is suitable for studies with a limited sample size and provides flexibility and efficiency in handling different integration levels and smaller datasets, particularly in fields such as tourism, environmental and economics. The ARDL regression model is stated as below:

$$Y_t = \beta_0 + \sum_{i=1}^{p} \beta_i Y_{t-i} + \sum_{j=0}^{q} \alpha_j \ X_{t-j} + \varepsilon_t$$

Where: t = sample periods; Y_{t-i} = lags of dependent variable; X_{t-j} = lags of independent variables; α, β = coefficients; p, q = chosen lag lengths; ε = the error terms.

3.6.2.1 ARDL Bound Cointegration Test

The ARDL Bound test is employed to detect the long-run cointegration relationship between the variables. The test checks the model for cointegration, which indicates that the dependent variable has a long-run equilibrium relationship with the independent variables. It interprets long-run and short-run coefficients with an Error Correction Model (ECM) term to capture the adjustment speed from the shock back to the equilibrium. The test could be conducted through the test statistic or the p-value approach. The test statistic value and the p-value could be obtained from the EViews software.

The hypotheses are as follows:

H_0: There is no long-run cointegration between variables.
H_1: There is long-run cointegration between variables.

The critical value of the bound test is based on the special bounds critical values tabulated by Pesaran et al. (2001). If the test statistic is larger than the upper bound critical value, the model consists of cointegrating variables; if the test statistic is lower than the lower bound critical value, the model does not consist of cointegrating variables; if the test statistic is between the upper and lower bound critical values, the result is inconclusive. As for the p-value approach, reject H_0 if the p-value is less than the significance level (0.05), which indicates no long-run cointegration between the variables.

3.6.3 Granger Causality Test

The Granger Causality Test is an econometric tool used to examine whether past values of one variable help predict another. Granger causality does not imply true causation in a strict sense, but it measures predictive ability based on temporal precedence and correlation of lagged values. In applied research, this test is useful for determining the direction of influence between variables (Granger, 1969). For instance, if TA are found to Granger-cause carbon emissions, it indicates that tourist activity influences environmental quality. Conversely, if emissions Granger-cause TA, it suggests that environmental conditions affect tourism demand. The p-value and the test statistic value could be obtained from the EViews software, or the test statistic value could be calculated by the following formula:

$$F = \frac{\frac{(RSS_R - RSS_{UR})}{m}}{\frac{RSS_{UR}}{(n-k)}}$$

Where RSS = residual sum of squares; R = restricted model (without lags); UR = unrestricted model (with lags); m = number of lags; n = sample size; k = number of parameters in unrestricted model.
The following are the hypotheses of the test developed:

H_0: The variable X does not Granger-cause the variable Y.
H_1: The variable X Granger-causes the variable Y.

Do not reject the H_0, which represents the variable X does not Granger-cause the variable Y, if the p-value or the critical value from the F-distribution is larger than the significance level (0.05), or the test statistic value.

3.6.4 Diagnostic Tests

3.6.4.1 Jarque-Bera Normality Test

To conduct a regression analysis, the assumption of normality for the model is necessary for the model to be considered reliable. A regression analysis assumes that the residuals of the model are normally distributed. Therefore, the Jarque-Bera normality test is employed. The test compares the test statistic and the critical value, or the p-value and the significance level. The p-value and the test statistic could be obtained by reliable software such as EViews, or the test statistic could be calculated through the following equation:

$$JB = n\left[\frac{S^2}{6} + \frac{(K-3)^2}{4}\right]$$

Where n = sample size; S = sample skewness; K = sample kurtosis
The hypotheses of the test are as follows:

H_0: The model's residuals are not normally distributed.
H_1: The model's residuals are normally distributed.

The H_0 is not rejected, which shows no normality issue in the model, if the p-value is larger than the significance level (0.05), or the test statistic is less than the critical value from the $\chi 2$ distribution (Jarque & Bera, 1987).

3.6.4.2 Breusch Pagan Lagrangian Multiplier (LM) Heteroskedasticity Test

The heteroskedasticity issue occurs when the model's residuals do not have equal variance, which indicates that the data points do not spread evenly. In this case, the Breusch Pagan heteroskedasticity test, a statistical procedure, is employed to determine whether the variance of the model's residuals is different (Herwartz, 2005). The Breusch Pagan Heteroskedasticity test's critical value is determined from the $\chi 2$ distribution. No heteroskedasticity issue is detected if the test statistic value is less than the critical value. Its test statistic is calculated by:

$$LM = n \times R^2$$

where n is denoted as the sample size, and R^2 is the R-squared.
As for the hypotheses applied are:

H_0: There is no heteroskedasticity issue.
H_1: There is a heteroskedasticity issue.

The p-value approach applies to the Breusch Pagan heteroskedasticity test as well. Compare the p-value obtained from the software with the significance level to decide whether to reject H_0, which leads to the results of the Breusch Pagan Heteroskedasticity test.

3.6.4.3 Breusch-Godfrey Lagrangian Multiplier (LM) Autocorrelation Test

When a variable is correlated with a lagged version of itself, measuring the similarity between the samples by utilising time series data, an autocorrelation issue occurs. The autocorrelation, also known as serial correlation, could be detected by applying the Breusch-Godfrey Lagrangian Multiplier (LM) autocorrelation test. The autocorrelation issue is detected if the test statistic value is larger than the critical value from the $\chi 2$ distribution.
The following are the hypotheses developed:

H_0: There is no autocorrelation issue in the model.
H_1: There is an autocorrelation issue in the model.

The test could be done by comparing the p-value from the EViews with the significance level. Reject H0 if the p-value is less than the significance level (0.05), which indicates that there is an autocorrelation issue in the model (Brüggemann et al., 2005).

CHAPTER 4: DATA ANALYSIS

4.1 Unit Root Test

Table 4.1

Augmented Dicky-Fuller test and Phillips-Perron test

	ADF		PP	
Variables	Intercept	trend	Intercept	Trend
Level				

LogTA	-3.7443***	-3.6692**	2.6718*	-2.6371
LogCO2	-0.6496	-2.6554	-0.4368	-2.4048
LogGDP	-0.7499	-3.072998	-0.8668	-3.1539
LogFDI	-3.9953***	-5.1281***	-3.9783***	-14.16396***
1st Difference				
LogTA	-4.6371***	-4.7321***	-9.5856***	-9.1501***
LogCO2	-6.4430***	-6.3543***	-6.4457***	-6.3581***
LogGDP	-6.0825***	-5.9670***	-7.5431***	-8.6847***
LogFDI	-6.5697***	-6.4354***	-27.1937***	-26.4030***

*Note: Significant levels at 1%, 5%, and 10% levels are indicated by ***, **, and *.*

The unit root tests are used to confirm the statistical properties of a variable, such as whether the mean and variance of the model remain constant over time. If a model consists of a unit root, or non-stationary, this can lead to spurious regression results, which means the reason the variables appear to be related is due to the sharing of a common trend. To ensure the ARDL model is valid, confirming that the variables are not integrated at an order higher than one is essential.

One of the main differences between the ADF and PP tests is the different strategies to handle autocorrelation in the error terms. The ADF includes lagged differences of the dependent variable in the regression equation to control for higher-order autocorrelation. Comparatively, the PP test utilizes non-parametric statistical methods to adjust for the issues in the error term, instead of including lagged differences. This makes the PP test more robust when the ADF cannot adequately capture autocorrelation, while the ADF remains a standard for controlling higher-order processes. Therefore, conducting both tests provides more comprehensive validation of the data's stationarity.

The results provided in **Table 4.1** show the outcome of both the ADF and the PP test at their level forms, and after first differencing. For the ADF test result, the variables demonstrate varying levels of stationarity. At the level form, LogTA and LogFDI are stationary at the significance level of 0.01 and 0.05. However, the results of LogCO2 and LogGDP fail to support the rejection of the null hypothesis, meaning they are non-stationary. In contrast, after the first differencing, all four variables have become stationary at the significance level of 0.01. This ensures the variables are integrated of order I(0) and I(1), which justifies the ARDL model, as the ARDL model is specifically designed to handle variables with mixed integration levels.

The PP test results reinforce the reliability of the data properties. At the level form, LogTA shows stationarity at the significance level of 0.1, while LogFDI shows stationarity at the significance level of 0.01. However, LogCO2 and LogGDP maintain non-stationarity with a unit root. Moreover, all of the variables achieve stationarity at the significance level of 0.01 after first differencing, which is the same result as the ADF. The stationarity of all variables shown by both ADF and PP tests confirms the validity of the ARDL model and avoids the risk of spurious results.

4.2 ARDL and ARDL Bound Cointegration Test

Table 4.2.1

Long-run Coefficients (Level Equation)

Variable	Coefficient	Standard Error	t-Statistic	p-value
LogCO2	7.1258*	3.7005	1.9257	0.0747
LogGDP	-0.0217	1.8233	-0.0119	0.9907
LogFDI	-3.2904**	1.3568	-2.4251	0.0294

Constant (C)	-2.7703	12.1230	-0.2285	0.8225

*Note: Significant levels at 1%, 5%, and 10% levels are indicated by ***, **, and *.*

The ARDL long-run coefficients, which is presented in **Table 4.2.1**, the results show a comprehensive view of the variables influencing tourism arrival in the long term. The main observation is the relationship between CO2 and TA. The results show that LogCO2 have a positive and statistically significant impact on LogTA at the significance level of 0.10, with a coefficient of 7.1258 and a p-value of 0.0747. Given the log-log model, this coefficient represents an elasticity. Therefore, the result can be understood as a 1% increase in CO2, on average, is associated with a 7.1258% increase in TA in the long run. This shows a relationship of a high sensitivity between the variables, suggesting that tourism growth in this context is strongly linked to carbon-intensive activities.

Furthermore, LogFDI emerges as a highly significant driver, showing a negative impact at the significance level of 0.05 with a coefficient of -3.2904 and a p-value of 0.0294. This implies that a 1% increase in FDI results in a 3.29% decrease in TA, which may suggest that industrial or commercial-focused investments are competing with the tourism sector for resources or detracting from the destination's appeal (Munir and Iftikhar, 2021).

In contrast, GDP per capita was found to be statistically insignificant, with a high p-value of 0.9907. This suggests that general economic wealth is not a primary factor in attracting tourists within this specific model.

Overall, the significant positive impact of CO2 shows while TA are increasing, they are doing so at a notable environmental cost, which highlight the tension between industry growth and environmental sustainability.

Table 4.2.2

Bound test

Test statistic	Value
F-statistic	4.2176**

*Note: Significant levels at 1%, 5%, and 10% levels are indicated by ***, **, and *.*

According to the bound test results on **Table 4.2.2**, the calculated F-statistic is 4.2176. This value is compared against the critical value bounds at the significance level of 0.05, where the upper bound value is 3.67. Since the F-statistic exceeds this upper bound, the null hypothesis of no cointegration is rejected.

This statistical evidence confirms the existence of a stable long-run cointegrated relationship among the variables. The result indicates that TA, CO2, GDP, and FDI move together in a long-term equilibrium, justifying the further estimation and interpretation of the long-run coefficients to understand the specific impact of each variable.

4.3 Granger Causality Test

Table 4.3

Granger Causality test

Cause	Effect	Observation	F-stat	p-value	Result
CO2	TA	25	0.2243	0.9459	n.s.
TA	CO2	25	5.6474	0.0047	*
GDP	TA	25	1.1161	0.3958	n.s.

TA	GDP	25	0.3300	0.8865	n.s.
FDI	TA	25	0.3382	0.8813	n.s.
TA	FDI	25	3.1935	0.0394	*

*Note: "n.s." = not significant; * = $p < 0.05$.*

The pairwise Granger causality test result shown in **Table 4.3** reveals that the Granger causality involving TA is mostly negative, except for TA causing CO2 (p-value, 0.0047) and TA causing FDI (p-value, 0.0394). Transportation cost is a challenge that cannot be avoided for the tourism sector, as it requires travelling between different locations. Furthermore, increasing international tourism leads to rising CO2 directly, especially through air or water transportation (Organization, 2019). Apparently, it has been a problem for Singapore's tourism sector as well. This is because Singapore, as an island nation that is also a global aviation Hub, owns one of the world's busiest airports, Changi Airport. Singapore's airport contributed to 60,000 jobs across industries, such as manufacturing and tourism (*Global Aviation Hub*, 2026). Therefore, in short-term, those factors have been contributing to Singapore's TA to Granger cause CO2.

Other than that, the test result also indicates that FDI is Granger-caused by TA. This suggests that TA attracts FDI, which supports the Tourism-Led-Growth Hypothesis (TLGH). This hypothesis states that the tourism development, which includes TA's growth, leads to the demand for tourism-related products and services that attract investment increases, such as hotels, resorts, and entertainment (Fan & Ha, 2025). As a result, this causes Singapore's TA to Granger-cause FDI.

4.4 Diagnosistic Test

4.4.1 Jarque-Bera Normality Test

Table 4.4.1

Jarque-Bera normality test

Statistic	Value
Mean	-3.45 x 10^{-14}
Median	0.0183
Std. Dev.	0.4532
Skewness	-0.7822
Kurtosis	3.2718
Jarque-Bera	2.7319
Probability	0.2551

The Normality test results shown in **Table 4.4.1** indicate that the model fulfilled the normality assumption. The Jarque-Bera statistic (2.7319) with a p-value of 0.2551 provides no evidence to reject the null hypothesis, confirming that the model residuals are normally distributed. The skewness statistic of –0.7822 and the kurtosis statistic of 3.2718 are both relatively close to the ideal value for a normal distribution.

The importance of the Jarque-Bera normality test to the research will never be overstated, as it is the "gatekeeper" for the validity of the entire analysis. Most classical linear regression models, such as the ARDL framework, rely on the normality assumption to ensure the estimated coefficients are reliable and efficient. If the model residuals did not pass the Jarque-Bera normality test, the results of the t-tests and F-tests that are serving as the key determinants of the significance of the variables could be misleading or biased. These diagnostic test results indicate that the normality assumption holds well, which supports the reliability of the regression estimates, and the findings' validity is robust enough for policymaking and recommendations.

4.4.2 Breusch Pagan Lagrangian Multiplier (LM) Heteroskedasticity Test

Table 4.4.2

Breusch Pagan Lagrangian Multiplier (LM) Heteroskedasticity Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.9968	Prob. F (11,14)	0.4930
Scaled explained SS	3.7610	Prob. Chi-Square (11)	0.9764

When the variance of the model error terms is not constant across all levels of the independent variables, it is referred to as heteroskedasticity. A reliable and efficient regression model must satisfy the homoskedasticity assumption. Homoskedasticity is when the spread of the errors remains uniform throughout the entire data range. The presence of heteroskedasticity reveals biased and misleading standard errors of the variables' coefficients.

The Breusch-Pagan LM Heteroskedasticity test was conducted to confirm the stability of variance. Based on the outcome provided in **Table 4.4.2**, the F-statistic of 0.9968 has a p-value of 0.4930, the Obs*R-squared statistic has a p-value of 0.4088, and the Scaled explained SS of 3.761 has a p-value of 0.9764. Since all the p-values are larger than the conventional 0.05 and 0.10 significance levels, the results indicate not to reject the null hypothesis of homoskedasticity, which means the standard errors of the variables' coefficient are unbiased. These results reveal that the residuals show constant variance, which satisfies one of the crucial classical assumptions of the regression model.

4.4.3 Breusch-Godfrey Lagrange Multiplier (LM) Autocorrelation Test

Table 4.4.3

Breusch-Godfrey Lagrange Multiplier (LM) Autocorrelation Test

Breusch-Godfrey LM Autocorrelation Test			
F-statistic	1.8660	Prob. F (4,10)	0.1931
Obs*R-squared	11.1122	Prob. Chi-Square (2)	0.0253
Durbin-Watson	2.4172		

Autocorrelation refers to the correlation of the model residuals with their own past values. And the autocorrelation test is a critical diagnostic to ensure the residuals are independent of one another. Satisfying the assumption of no autocorrelation issues is important as it confirms that the residuals do not contain patterns that the model failed to capture. If an autocorrelation issue exists in a model, it indicates that the estimate of the model is unreliable, potentially leading to inaccurate conclusions.

From **Table 4.4.3**, the outcome of the Breusch-Godfrey Lagrange Multiplier (LM) Autocorrelation Test shows that the F-statistic, 1.8660, with the p-value of 0.1931 does not support rejecting the null hypothesis, which states no autocorrelation issue in the model residuals. This demonstrates that the ARDL model is accurately specified and unbiased. And the findings of the study are statistically robust and efficient.

CHAPTER 5: CONCLUSION AND IMPLICATIONS

5.1 Major Findings

Singapore, as a high-income developed country, has rising trends in both TA and CO2 from the year 1995 to 2024. From a theoretical perspective, this indicates that it is in the upward sloping stage of the EKC, which is the stage where higher environmental degradation is associated with higher national income. Therefore, although being a high-income developed country, this suggests that its tourism sector is yet to meet the specific turning point. This is due to the downward sloping stage after the turning point, which demonstrates a situation where clean energy consumption is encouraged. At this stage, as the national income grows, the environmental degradation becomes lower.

Based on the findings above, the relationship between the variables of CO2, GDP, and FDI on TA in Singapore from the year 1995 to 2024 was examined. The research conducted was an ARDL Bound test to confirm the stable long-run cointegrated relationship among these variables, whether they move together in a long-term equilibrium. The empirical results from the ARDL Bound test reveal that the variables have a significant long-run cointegrated relationship (F-statistic, 4.2176 > upper bound critical value, 3.67). Specifically, the long-run coefficient of CO2 (7.1258*) indicates a positively significant impact on TA. This suggests that Singapore's rising CO2, which serves as a proxy for industrial activity and infrastructure expansion, is associated with its increased tourism demand. These findings can be interpreted as 1% increase in CO2, on average, leads to 7.1258% rise in TA in the long run, ceteris paribus. This outcome agrees with the literature that suggests that developed economies' CO2 urges during industrial peaks motivate tourism by boosting connectivity and urban appeal.

The Granger causality test shows that TA and CO2 have a unidirectional causality flow from TA to CO2 (p-value, 0.0047), meaning that TA Granger-caused CO2. This demonstrates that the past value of TA contains significant information that can be used to predict future CO2. So, CO2 is shown to be an outcome of TA, instead of a motivator that influences the tourists' decision to visit. This outcome goes against the Economic-Led-Tourism-Hypothesis proposed. The result shows TA Granger causes FDI, which aligns with the Tourism-Led-Growth Hypothesis.

The empirical results from the ARDL and Granger-causality tests provide a complementary understanding of Singapore's tourism-emissions nexus. The ARDL long-run estimate reveals a significant positive association where CO2, serving as a proxy for the energy-intensive urban infrastructure and high-quality services, act as a pull factor for international tourists (Katircioğlu, 2014). Conversely, the Granger-causality test identifies a unidirectional flow from TA to CO2. The ARDL confirms that tourism and emissions are "cointegrated" (they share a long-term path), while Granger-causality clarifies the functional direction: it is the tourism sector's growth that drives the demand for energy and subsequent carbon output (Al-Mulali et al., 2015). This suggests that while Singapore's carbon-heavy industrial success attracts visitors, the actual presence of these visitors is the catalyst for environmental degradation, placing the nation firmly on the upward-sloping side of the EKC.

The diagnostic tests, which include the normality (p-value, 0.2551), heteroscedasticity (p-value, 0.493), and autocorrelation tests (p-value, 0.1931), confirmed the robustness of the model, ensuring the model is reliable and free from issues like heteroscedasticity and autocorrelation. Other than that, the unit root tests, ADF and PP test confirmed the stationarity of the data as well, which further vertified the validity of the ARDL model.

5.2 Implications of the study

5.2.1 Policymaking

The most important discovery for policymakers is that CO_2 are caused by TA rather than the other way around. This means that CO_2 is largely a consequence of growing tourist activity rather than a deterrent to it. For Singapore's government bodies, this finding suggests that managing CO_2 cannot be separated from managing tourism growth itself. Environmental policies that focus solely on emission reduction targets without addressing the volume and nature of tourist activity may therefore fall short.

At the same time, the long-run ARDL results show that CO_2 has a significant positive relationship with TA, which is consistent with the idea that Singapore's carbon-intensive infrastructure. This puts policymakers in a difficult position, where the very infrastructure driving tourism growth is also driving emissions. Given this, future policies should look at decarbonising tourism infrastructure rather than simply capping growth, which aligns with Singapore's broader commitments under the Singapore Green Plan and its targets for SDG 13 (Climate Action) and SDG 8 (Decent Work and Economic Growth) (United Nations, 2025).

5.2.2 Tourism Sector

For tour operators, travel agencies, and other tourism service providers within Singapore's tourism industry, the Granger causality result carries a clear message, which the growth of TA directly contributes to rising CO_2, which means the tourism sector itself owns accountability for a portion of Singapore's environmental footprint.

The finding that FDI has a significant negative long-run impact on TA (ARDL coefficient of -3.2904) is also relevant here since the result suggest that investment flows directed towards industrial development compete with tourism-related development (Munir and Iftikhar, 2021). Tour operators and industry associations could use this as an argument for directing more investment specifically into tourism infrastructure and ecotourism experiences. Practically, this means tour operators should consider collaborating with locals to develop sustainable tour packages, reducing reliance on carbon-intensive transport options, and training staff to uphold environmental standards in line with bodies such as the Global Sustainable Tourism Council (GSTC, 2025). By doing so, not only would it reduce the sector's contribution to CO_2, but it could also strengthen Singapore's reputation as a responsible tourism destination.

5.2.3 Business sectors

Local businesses that depend on tourism revenue, including hotels, restaurants, retail shops, and many more, would benefit from acknowledging the long-run dynamics identified in this study. Since CO_2 and TA move together in long-run equilibrium, businesses can expect that high tourism demand will coincide with high environmental pressure.

The findings support the case for businesses to invest in waste reduction programmes, energy-efficient operations and machines, and community-based marketing strategies that would help mitigate the environmental side effects of tourism growth while maintaining competitiveness. As highlighted in section 1.5, businesses that align their operations with sustainable practices are also better positioned to retain customer loyalty and meet the expectations of increasingly environmentally conscious tourists.

5.2.4 Research contributions

From an academic standpoint, this study contributes to the relatively limited body of empirical research on the tourism-CO2 nexus specifically within Singapore. While studies such as Raihan and Tuspekova (2022b) and Katircioğlu (2014) have examined related questions for Singapore, this study extends the sample period to 2024 and incorporates FDI as an additional control variable, which offers a more updated and comprehensive picture of its relations.

The finding that TA Granger-causes CO2 but not the reverse challenges the Economic-Led-Tourism Hypothesis in the context of Singapore, which adds mixed results seen in the existing literature. This provides a useful reference point for future researchers studying similar small, developed island economies where tourism growth is driven by urban infrastructure rather than natural endowments.

5.3 Recommendation for Future Studies

There are several areas where future studies could improve on the aspect of this research. Two of the most notable constraints are that this study covers only Singapore and uses total CO_2 rather than emissions specific to the tourism sector. Addressing these would produce more precise and comparable findings.

5.3.1 Expanding Beyond a Single Country

Since this study is limited to Singapore, the findings may not apply to other countries with different economic structures or tourism profiles. Future research could extend the scope to include other developed economies in the Asia-Pacific region, such as Hong Kong, South Korea, or Japan, which share similar characteristics of high urbanisation and heavy reliance on international tourism. A panel data approach across multiple countries is suggested for cross-country comparisons and more generalisable conclusions. It would also help determine whether the positive long-run relationship found between CO_2 and TA in Singapore is a pattern consistent across similar economies, or unique to Singapore's circumstances as a small island state.

5.3.2 Expanding for In-depth Studies

Since this study has provided a basic understanding about the nexus between Singapore's tourism industry and environmental degradation, future studies are suggested to move toward more complex econometric frameworks. First, the inclusion of a Vector Error Correction Model (VECM) or a standard ECM is suggested to determine the "speed of adjustment," which measures how quickly the tourism-emissions relationship returns to its long-run equilibrium following a sudden economic shock (Hassan et al., 2020). Second, researchers should employ

Non-linear ARDL (NARDL) to examine potential asymmetries; this is critical to see if tourists react more strongly to increases in carbon emissions than to environmental improvements (Chen, 2022). Finally, to ensure the validity of the results, robustness tests such as DOLS and FMOLS are recommended. These tests provide a vital check by correcting for endogeneity and serial correlation, ensuring that the estimated impact of CO2 on TA is unbiased and statistically sound (Dogan & Aslan, 2017).

5.3.3 Using Tourism-Specific Emission Data

This study relies on total CO2 as a proxy for environmental degradation, which includes emissions from sectors unrelated to tourism, such as manufacturing and energy production. This reduces the precision of the findings when interpreting the relationship between the environment and tourist flows. Future studies should attempt to use emission data that is specific to the tourism sector, such as transport-related CO2 from air travel and ground transportation, which the World Tourism Organization (2019) has estimated to be a major contributor to the sector's overall carbon footprint. Diverging emissions by sector would allow researchers to draw a clearer link between tourism activity and environmental impact, and would also help evaluate whether Singapore's ecotourism policies are actually reducing the carbon intensity of its tourism industry.

5.3.4 Including Additional Variables

The model in this study includes CO2, GDP, and FDI as explanatory variables. Future research could consider adding other relevant factors such as trade openness, energy consumption, or renewable energy usage, which have been found to influence both tourism development and carbon emissions in prior studies (Raihan & Tuspekova, 2022b; Ben Jebli et al., 2019). Incorporating tourism supply side indicators, such as hotel capacity or airport connectivity, could also provide a more complete picture of what drives international tourist flows in Singapore.

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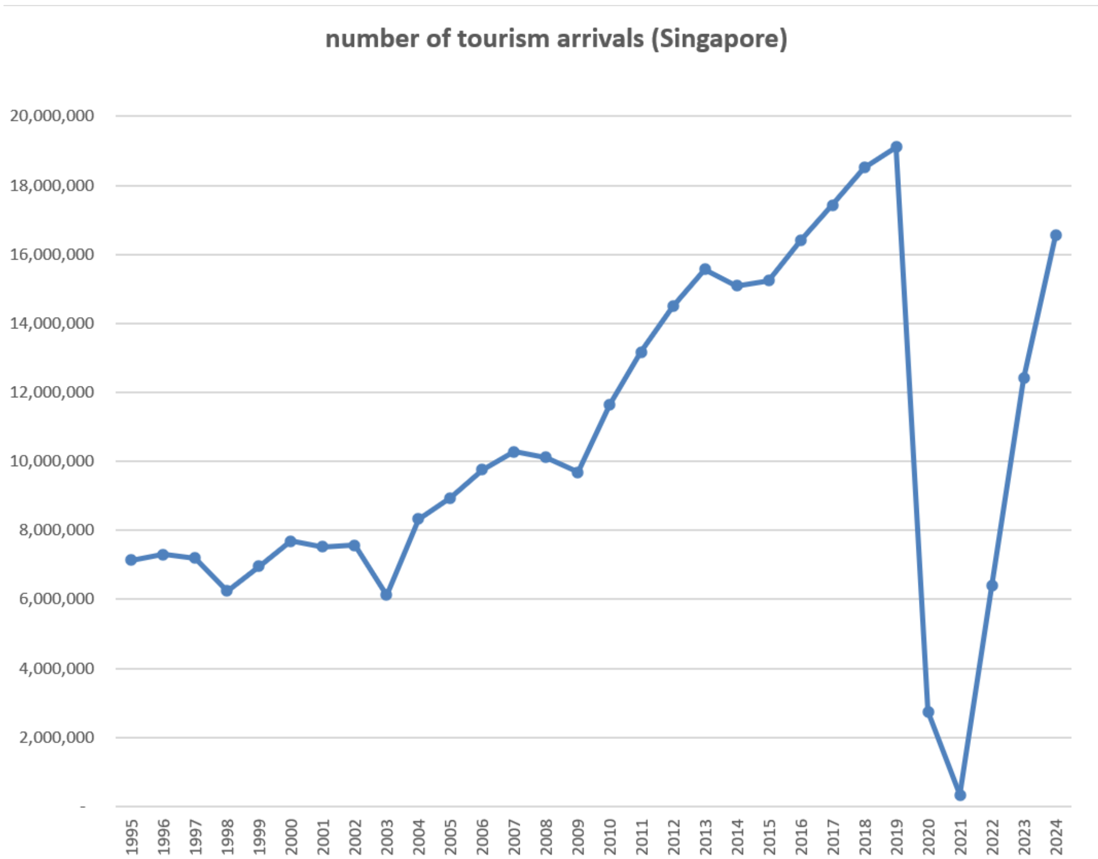
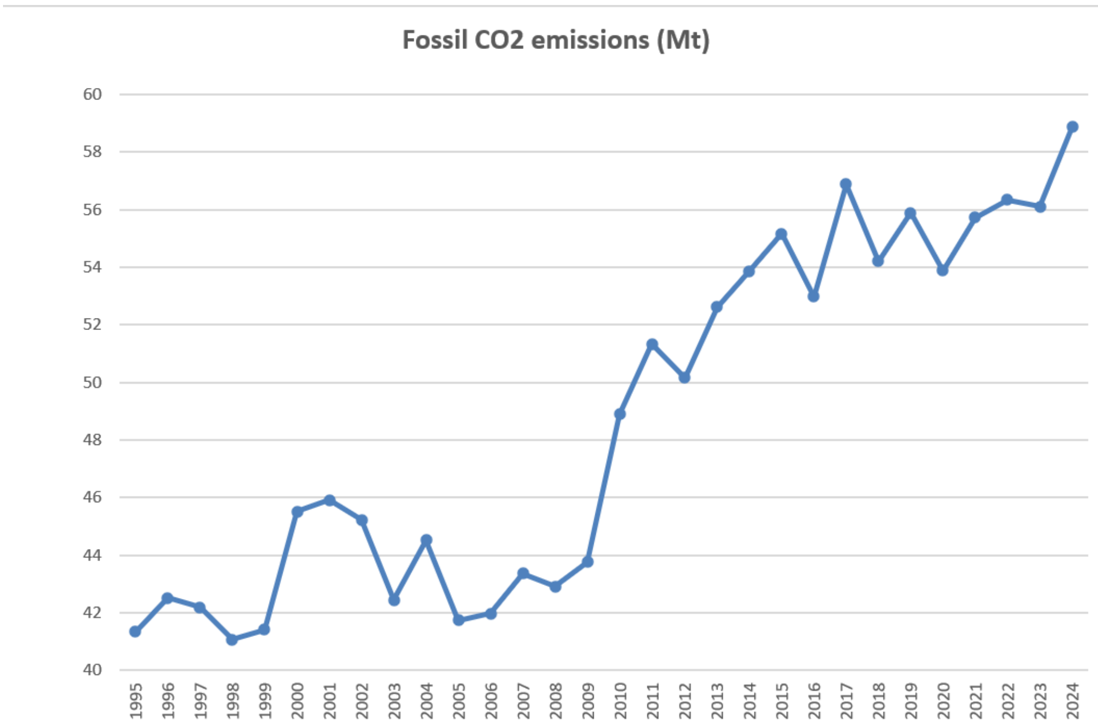
APPENDICES

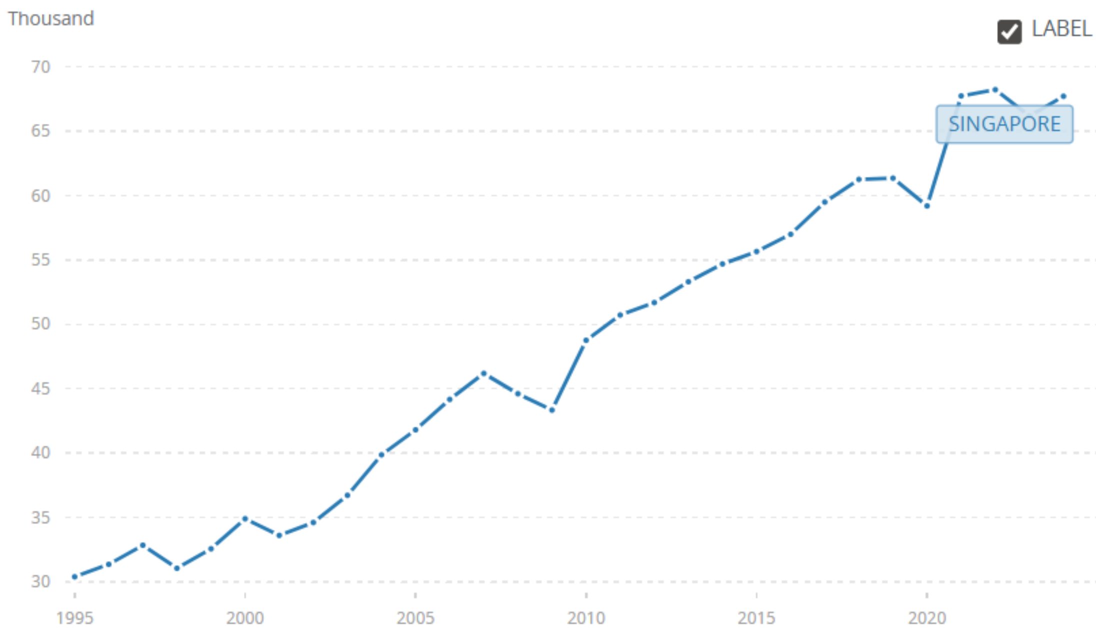
Appendix 1.1.1: Trend of tourism arrivals in Singapore from 1995 to 2024



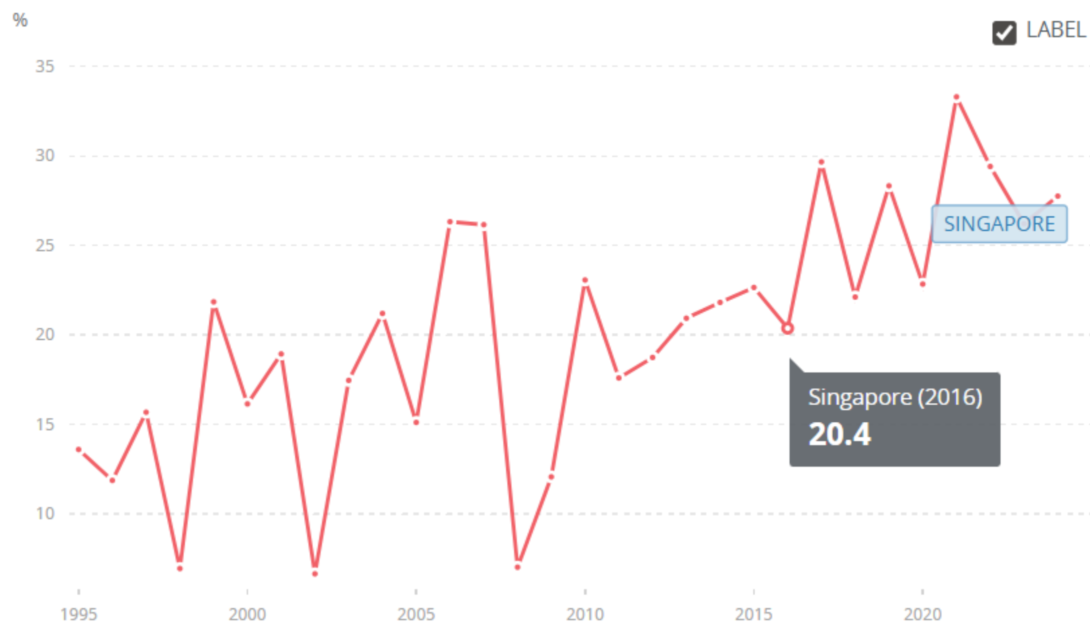
Appendix 1.1.2: Trend of CO2 in Singapore from 1995 to 2024



Appendix 1.1.3: Trend of GDP (constant 2015 USD) in Singapore from 1995 to 2024



Appendix 1.1.4: Trend of FDI, net inflow (% of GDP) in Singapore from 1995 to 2024



Appendix 1.1.5: Dataset of TA, CO2, FDI and GDP of Singapore from year 1995 to 2024

Year	TA	CO2	FDI	GDP
1995	7,137,000	41.3412	13.60039465	30,380
1996	7,292,000	42.5208	11.872466	31,349
1997	7,198,000	42.1917	15.68237091	32,835
1998	6,242,000	41.0625	6.950624804	31,043
1999	6,958,000	41.4082	21.84920346	32,557
2000	7,691,000	45.5193	16.14889045	34,890
2001	7,522,000	45.9066	18.93986069	33,598
2002	7,567,000	45.2172	6.653665882	34,599
2003	6,127,000	42.4426	17.46241537	36,710
2004	8,329,000	44.523	21.20272375	39,857
2005	8,943,000	41.7315	15.11335885	41,798
2006	9,751,000	41.9694	26.3271523	44,159
2007	10,285,000	43.3583	26.16198888	46,179
2008	10,116,000	42.9155	7.023286082	44,602
2009	9,683,000	43.7607	12.07109441	43,332
2010	11,642,000	48.8859	23.06947168	48,752
2011	13,171,000	51.3367	17.59603141	50,714
2012	14,496,000	50.1515	18.74352442	51,679
2013	15,568,000	52.6259	20.93448104	53,299
2014	15,095,000	53.8631	21.81848808	54,682
2015	15,231,500	55.1746	22.65418269	55,646
2016	16,403,000	52.9724	20.37662876	56,987
2017	17,425,000	56.8881	29.67061262	59,485
2018	18,508,000	54.2117	22.11837726	61,250
2019	19,116,000	55.8876	28.33155043	61,346
2020	2,742,000	53.8768	22.84108284	59,190
2021	333,644	55.7179	33.30458087	67731
2022	6,395,935	56.3467	29.41423786	68219
2023	12,403,322	56.1013	26.21410357	66167
2024	16,546,789	58.8681	27.75756479	67707

Appendix 4.1: Augmented Dicky-Fuller test and Phillips-Perron test

	ADF		PP	
Variables	**Intercept**	**trend**	**Intercept**	**Trend**
Level				
LgTA	-3.7443***	-3.6692**	2.6718*	-2.6371
	0.0088	0.0417	0.0910	0.2679
LgCO2	-0.6496	-2.6554	-0.4368	-2.4048
	0.8440	0.2616	0.8898	0.3695
LgGDP	-0.7499	-3.072998	-0.8668	-3.1539
	0.8182	0.1313	0.7842	0.1134
LgFDI	-3.9953***	-5.1281***	-3.9783***	-14.16396***
	0.0046	0.0015	0.0048	0.0000
Overall	20.9638***	25.5288***	16.1794**	273.37***
	0.0072	0.0013	0.0399	0.0000
1st Difference				
LgTA	-4.6371***	-4.7321***	-9.5856***	-9.1501***
	0.0012	0.0045	0.0000	0.0000
LgCO2	-6.4430***	-6.3543 ***	-6.4457***	-6.3581***
	0.0000	0.0001	0.0000	0.0001
LgGDP	-6.0825***	-5.9670***	-7.5431***	-8.6847***
	0.0000	0.0002	0.0000	0.0000
LgFDI	-6.5697***	-6.4354***	-27.1937***	-26.4030***
	0.0000	0.0001	0.0001	0.0000
Overall	80.9381***	56.7006***	103.6629***	355.771***
	0.0000	0.0000	0.0000	0.0000

Appendix 4.2: ARDL and ARDL Bound Cointegration Test

ARDL Long Run Form and Bounds Test
Dependent Variable: D(TA)
Selected Model: ARDL(2, 0, 4, 2)
Case 2: Restricted Constant and No Trend
Date: 03/30/26 Time: 16:02
Sample: 1995 2024
Included observations: 26

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.265534	9.781029	-0.231625	0.8202
TA(-1)*	-0.817786	0.194677	-4.200739	0.0009
CO2_TONS**	5.827375	3.024525	1.926707	0.0746
GDP_PER_CAPITA(-1)	-0.017750	1.491375	-0.011902	0.9907
FDI____OF_GDP_(-1)	-2.690836	1.054063	-2.552822	0.0230
D(TA(-1))	0.276556	0.209080	1.322726	0.2071
D(GDP_PER_CAPITA)	-4.472467	4.604847	-0.971252	0.3479
D(GDP_PER_CAPITA(...	13.85538	4.383665	3.160684	0.0069
D(GDP_PER_CAPITA(...	8.876324	4.964793	1.787854	0.0955
D(GDP_PER_CAPITA(...	8.928701	3.875524	2.303869	0.0371
D(FDI____OF_GDP_)	-0.428188	0.467549	-0.915813	0.3753
D(FDI____OF_GDP_(-1))	1.051702	0.546047	1.926029	0.0747

* p-value incompatible with t-Bounds distribution.
** Variable interpreted as Z = Z(-1) + D(Z).

Levels Equation
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO2_TONS	7.125791	3.700455	1.925652	0.0747
GDP_PER_CAPITA	-0.021705	1.823318	-0.011904	0.9907
FDI____OF_GDP_	-3.290389	1.356813	-2.425087	0.0294
C	-2.770325	12.12295	-0.228519	0.8225

EC = TA - (7.1258*CO2_TONS -0.0217*GDP_PER_CAPITA -3.2904
*FDI____OF_GDP_ -2.7703)

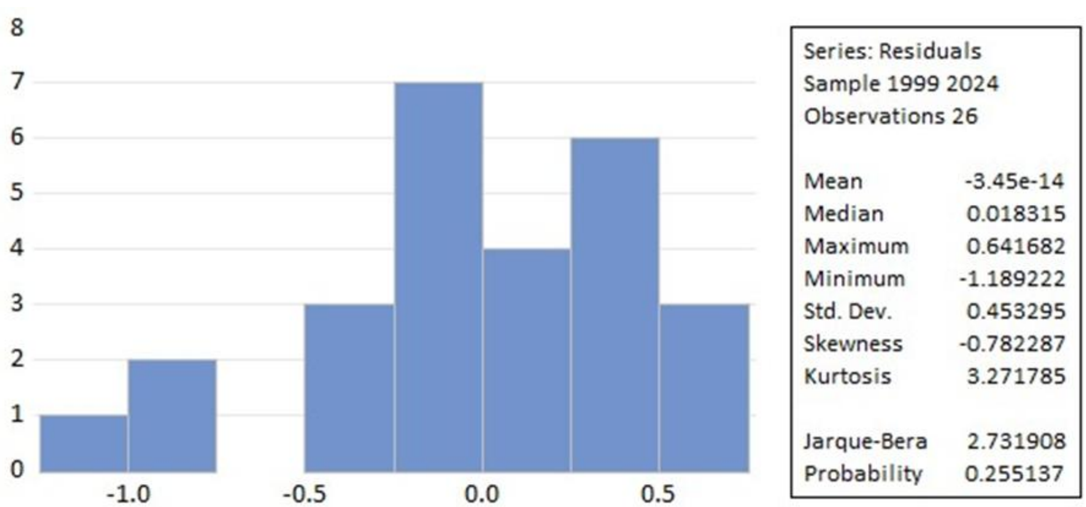
F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
		Asymptotic: n=1000		
F-statistic	4.217561	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Actual Sample Size	26	Finite Sample: n=35		
		10%	2.618	3.532
		5%	3.164	4.194
		1%	4.428	5.816
		Finite Sample: n=30		
		10%	2.676	3.586
		5%	3.272	4.306
		1%	4.614	5.966

Appendix 4.3: Granger Causality

Pairwise Granger Causality Tests
Date: 04/01/26 Time: 13:11
Sample: 1995 2024
Lags: 5

Null Hypothesis:	Obs	F-Statistic	Prob.
CO2_TONS does not Granger Cause TA	25	0.22427	0.9459
TA does not Granger Cause CO2_TONS		5.64735	0.0047
GDP_PER_CAPITA does not Granger Cause TA	25	1.11612	0.3958
TA does not Granger Cause GDP_PER_CAPITA		0.32996	0.8865
FDI____OF_GDP_ does not Granger Cause TA	25	0.33822	0.8813
TA does not Granger Cause FDI____OF_GDP_		3.19348	0.0394
GDP_PER_CAPITA does not Granger Cause CO2_TONS	25	2.78197	0.0600
CO2_TONS does not Granger Cause GDP_PER_CAPITA		1.84825	0.1678
FDI____OF_GDP_ does not Granger Cause CO2_TONS	25	2.35727	0.0946
CO2_TONS does not Granger Cause FDI____OF_GDP_		3.21483	0.0386
FDI____OF_GDP_ does not Granger Cause GDP_PER_CAPITA	25	0.87631	0.5216
GDP_PER_CAPITA does not Granger Cause FDI____OF_GDP_		1.64568	0.2124

Appendix 4.4.1: Jarque-Bera Normality Test



Appendix 4.4.2: Breusch Pagan Lagrangian Multiplier (LM) Heteroskedasticity Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity

F-statistic	0.996844	Prob. F(11,14)	0.4930
Obs*R-squared	11.41975	Prob. Chi-Square(11)	0.4088
Scaled explained SS	3.760999	Prob. Chi-Square(11)	0.9764

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/24/26 Time: 18:32
Sample: 1999 2024
Included observations: 26

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-3.069252	4.907140	-0.625467	0.5417
TA(-1)	-0.035270	0.113890	-0.309684	0.7614
TA(-2)	0.155737	0.104895	1.484686	0.1598
GDP_PER_CAPITA	-3.281817	2.310251	-1.420546	0.1773
GDP_PER_CAPITA(-1)	-0.537876	2.594698	-0.207298	0.8388
GDP_PER_CAPITA(-2)	2.078042	2.450193	0.848114	0.4106
GDP_PER_CAPITA(-3)	1.338420	2.165241	0.618139	0.5464
GDP_PER_CAPITA(-4)	0.955504	1.944350	0.491426	0.6307
FDI____OF_GDP_	0.308748	0.234569	1.316234	0.2092
FDI____OF_GDP_(-1)	0.285056	0.253267	1.125518	0.2793
FDI____OF_GDP_(-2)	-0.104851	0.273952	-0.382736	0.7077
CO2_TONS	-1.475461	1.517404	-0.972359	0.3474

R-squared	0.439221	Mean dependent var	0.197574
Adjusted R-squared	-0.001391	S.D. dependent var	0.303689
S.E. of regression	0.303900	Akaike info criterion	0.759803
Sum squared resid	1.292975	Schwarz criterion	1.340463
Log likelihood	2.122556	Hannan-Quinn criter.	0.927012
F-statistic	0.996844	Durbin-Watson stat	1.982994
Prob(F-statistic)	0.492978		

Appendix 4.4.3: Breusch-Godfrey Lagrange Multiplier (LM) Autocorrelation Test

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 4 lags

F-statistic	1.865992	Prob. F(4,10)	0.1931
Obs*R-squared	11.11220	Prob. Chi-Square(4)	0.0253

Test Equation:
Dependent Variable: RESID
Method: ARDL
Date: 03/24/26 Time: 19:26
Sample: 1999 2024
Included observations: 26
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TA(-1)	-0.544607	0.400606	-1.359459	0.2039
TA(-2)	0.417423	0.325720	1.281541	0.2289
GDP_PER_CAPITA	1.727210	4.503988	0.383485	0.7094
GDP_PER_CAPITA(-1)	-1.670515	5.208653	-0.320719	0.7550
GDP_PER_CAPITA(-2)	3.298965	5.046540	0.653708	0.5280
GDP_PER_CAPITA(-3)	-5.047861	4.450647	-1.134186	0.2832
GDP_PER_CAPITA(-4)	1.777756	4.489430	0.395987	0.7004
FDI____OF_GDP_	-0.234533	0.469206	-0.499851	0.6280
FDI____OF_GDP_(-1)	-0.171863	0.496962	-0.345827	0.7366
FDI____OF_GDP_(-2)	-0.100936	0.510299	-0.197797	0.8472
CO2_TONS	0.992026	3.300223	0.300593	0.7699
C	-1.330447	8.791310	-0.151337	0.8827
RESID(-1)	0.588326	0.447896	1.313533	0.2183
RESID(-2)	-0.088916	0.405538	-0.219255	0.8309
RESID(-3)	-0.568914	0.467505	-1.216915	0.2516
RESID(-4)	-0.529691	0.352917	-1.500892	0.1643

R-squared	0.427392	Mean dependent var	-3.45E-14
Adjusted R-squared	-0.431519	S.D. dependent var	0.453295
S.E. of regression	0.542350	Akaike info criterion	1.889448
Sum squared resid	2.941436	Schwarz criterion	2.663661
Log likelihood	-8.562820	Hannan-Quinn criter.	2.112393
F-statistic	0.497598	Durbin-Watson stat	2.417194
Prob(F-statistic)	0.892406		