



THE EFFECT OF MALAYSIA'S TRADING ACTIVITY ON ENVIRONMENTAL DEGRADATION

by

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DECLARATION

I want to emphasize which this project for my final year is an outcome of my own efforts. All concepts, methodologies, and conclusions presented herein are solely based on my own understanding and research. All sources referenced have been appropriately acknowledged, underscoring the authenticity and individual nature of this academic work.

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The Effect of Malaysia's Trading Activity on Environmental Degradation

ABSTRACT

Trading activity refers to the exchange of products and services between Malaysia and its international counterparts, contributing to growth in commerce. Conversely, though, environmental degradation refers to the deterioration of the environment, particularly as it relates to rising carbon dioxide (CO₂) emissions, which contribute significantly to climate change. While Malaysia has experienced rapid economic expansion as a result of its vast trading activities, worries about the environmental deterioration that is being caused by rising pollution and carbon emissions have also been voiced. There are two objectives of this study. First, to comprehensively examine the effect of Malaysia's trading activity on environmental degradation. Second, to test the existence of an Environmental Kuznets Curve (EKC) trend within Malaysia's trading activities. The impact of Malaysia's trading activity on environmental degradation between 1980 and 2020 is examined in this study. This study employs ARDL in EViews version 10.0 to analyse data from reliable sources, such as the World Bank. The variables this study employed include energy consumption, trade openness, Gross Domestic Product (GDP), and carbon dioxide emissions. The findings support the Environmental Kuznets Curve (EKC) pattern, which shows a curvilinear link between trade, economic expansion, energy use, and environmental deterioration. Initially, CO₂ emissions and energy consumption tend to rise with GDP per capita, which exacerbates environmental damage. The presence of a quadratic term, however, points to a potential turning point where the rate of environmental degradation slows down and moves closer to sustainability. This implies that trade openness, along with economic growth and energy consumption, influences environmental degradation. Aiming to achieve equilibrium between economic expansion and ecological well-being, recommendations to lessen the environmental impact of trading activities include adopting sustainable practices, promoting eco-friendly technologies, and strengthening regulatory measures for responsible waste management.

Keywords- Trading activity, environmental degradation, Autoregressive and Distributed Lag Model (ARDL), energy use, export, import, gross domestic product, carbon dioxide emission.

ABSTRAK

Aktiviti perdagangan merujuk kepada pertukaran produk dan perkhidmatan antara Malaysia dan rakan antarabangnya, menyumbang kepada pertumbuhan dalam perdagangan. Sebaliknya, kemerosotan alam sekitar merujuk kepada kemerosotan alam sekitar, terutamanya yang berkaitan dengan peningkatan pelepasan karbon dioksida (CO₂), yang menyumbang dengan ketara kepada perubahan iklim. Walaupun Malaysia telah mengalami perkembangan ekonomi yang pesat hasil daripada aktiviti perdagangannya yang luas, kebimbangan tentang kemerosotan alam sekitar yang disebabkan oleh peningkatan pencemaran dan pelepasan karbon juga telah disuarakan. Terdapat dua objektif dalam kajian ini. Pertama, untuk mengkaji secara menyeluruh kesan aktiviti perdagangan Malaysia terhadap kemerosotan alam sekitar. Kedua, untuk menguji kewujudan trend EKC dalam aktiviti perdagangan Malaysia. Kesan aktiviti perdagangan Malaysia terhadap kemerosotan alam sekitar antara tahun 1980 dan 2020 dikaji dalam kajian ini. Kajian ini menggunakan ARDL dalam EViews versi 10.0 untuk menganalisis data daripada sumber yang boleh dipercayai, seperti Bank Dunia. Pembolehubah yang digunakan oleh kajian ini termasuk penggunaan tenaga, keterbukaan perdagangan, Keluaran Dalam Negara Kasar (KDNK), dan pelepasan karbon dioksida. Penemuan ini menyokong corak Keluk Kuznets Alam Sekitar (EKC), yang menunjukkan hubungan lengkung antara perdagangan, pengembangan ekonomi, penggunaan tenaga dan kemerosotan alam sekitar. Pada mulanya, pelepasan CO₂ dan penggunaan tenaga cenderung meningkat dengan KDNK per kapita, yang memburukkan lagi kerosakan alam sekitar. Kehadiran istilah kuadratik, bagaimanapun, menunjukkan titik perubahan yang berpotensi di mana kadar kemerosotan alam sekitar semakin perlahan dan semakin menghampiri kemampanan. Ini menunjukkan bahawa keterbukaan perdagangan, bersama-sama dengan pertumbuhan ekonomi dan penggunaan tenaga, mempengaruhi kemerosotan alam sekitar. Bertujuan untuk mencapai keseimbangan antara pengembangan ekonomi dan kesejahteraan ekologi, cadangan untuk mengurangkan kesan alam sekitar aktiviti perdagangan termasuk mengamalkan amalan mampan, menggalakkan teknologi mesra alam dan mengukuhkan langkah pengawalseliaan untuk pengurusan sisa yang bertanggungjawab.

Kata kunci- Aktiviti perdagangan, kemerosotan alam sekitar, model autoregressive dan distributed lag (ARDL), penggunaan tenaga, eksport, import, keluaran dalam negara kasar, pembebasan karbon dioksida.

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LIST OF ABBREVIATIONS

ADF	Augmented-Dickey Fuller
ARDL	Autoregressive Distribution Lags
CDIAC	Carbon Dioxide Information Analysis Center
CO ₂	Carbon Dioxide
DOSM	Department of Statistic Malaysia
EC	Energy Consumption
EKC	Environmental Kuznets Curve
EX	Export
GDP	Gross Domestic Product
GDP ²	Gross Domestic Product of Square
IM	Import
LNEC	Logarithm of Energy Consumption
LNGDP	Logarithm of Gross Domestic Product
LNTOP	Logarithm of Trade Openness
PHH	Pollution Haven Hypothesis
PIR	Pollution-income Relationship
TOP	Trade Openness
WTO	World Trade Organization
Z	ZERO

LIST OF SYMBOLS

%	Percentage
>	Greater than
<	Less than
B	Parameters
ϵ	Time period
T	Error term



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CHAPTER 1

INTRODUCTION

1.0 Introduction

Malaysia has been gifted with variety of natural resources that can give benefit to the nation. Due to this, exploitation of natural resources is done in order to get profit out of the activities. Trading activity, is somehow one of the ways implemented by Malaysia to ensure the growth of economic income. Trading activity is the collective engagement of market participants in buying and selling securities, encompassing factors such as trading volume, bid-ask spread, and the actions of market makers (Regaieg & Hassini, 2023).

In Malaysia, trading activities involve mining, manufacturing, and agriculture. The manufacturing sector, specifically in the electronics, automotive, and consumer products industries, is a major contributor to the GDP. The strong relationship between this sector's growth and imports and exports highlights the role that trade openness plays in promoting economic growth. Trade openness that provides access to international markets promotes the flow of products and services, which encourages national industrialization and economic growth.

On the other hand, as trading activity increases, an issue called environmental degradation appears. This is because through trading activity, energy consumption will be heightened (Taasim et al., 2021). Higher energy consumption frequently results in higher

emissions of greenhouse gases like carbon dioxide, which fuel global warming and climate change. The greenhouse effect is exacerbated by the burning of fossil fuels for transportation, industrial processes, energy production, and heating.

The process of environmental degradation has impacts on both the general health of the environment and the capacity of the natural environment to support biological diversity. This process could begin completely spontaneously or it might be accelerated or started by human involvement. Environmentalists in some countries believed that although the development of trade would promote economic development, it would worsen their own environment, especially in countries or regions with backward economic development (Chen, 2023).

Trade is often assumed to enhance economic activity and, consequently, energy use. Based on World Trade Organization (WTO), if all else remains the same, this rise in economic activity and energy consumption will result in higher greenhouse gas emissions. Since everything that is done during trade activity will have an impact on the environment, trading activity and environment degradation are related and cannot be separated.

1.1 Background of Study

The expansion of trade activity in Malaysia has greatly increases the economic value, making it as one of the significant incomes for the nation. Trading activity however may have negative impact as it can contribute to environmental degradation. The depletion of environment can be traced with changes of climate that is caused by human made activity. This situation is the outcome of trading activity done as for the entrepreneur to fulfil the demand of their production.

Trading activity is important for countries including Malaysia as it depicts as a measure to a national success. In other word, trading activity contribute to the growth of gross domestic product (GDP) in Malaysia. For this particular reason, political strive their best to enhance the increase of GDP rate each year. As example, Malaysia has the increase and decrease trend in GDP growth as shown in the **Figure 1.1** below.

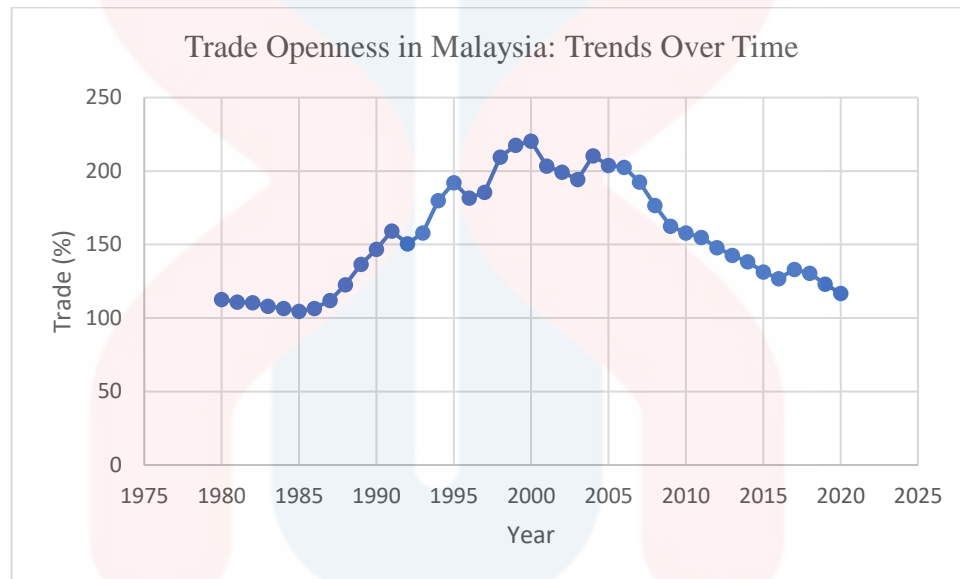


Figure 1.1: Malaysia- Trade openness from 1980-2020 (Source: The World Bank)

Based on the **Figure 1.1**, the x-axis, represents the years from 1980 to 2020. The y- axis, represents the trade as a percentage of Malaysia's GDP. Based on the graph, there are fluctuations in the data, with the trade (GDP%) values going up and down from year to year. Despite the fluctuations, there is an overall increasing trend in Malaysia's trade as a percentage of its GDP from 1980 to around 2000. During this period, the trade (GDP%) values generally show an upward trend, indicating an expansion of Malaysia's international trade relative to its GDP. Several peak years stand out in the data, indicating periods of relatively high trade (GDP%) ratios. Notable peaks occur in the late 1990s and

early 2000s, reaching the highest point in 2000. In the most recent years, the trade (GDP%) ratio remains relatively stable but shows a slight declining trend, with a dip in 2020.

Nevertheless, no matter what is the state of the trend of GDP, the environmental degradation will always occur. This is because, the greater the economic growth, the higher the probability of environmental degradation to happen. Pollution produced by the trading activity such as carbon dioxide can harm the nature as the greenhouse gases can lead to climate change.

Based on World Bank, Malaysia's greenhouse gas emissions based on the provided data suggests fluctuations in the earlier years, followed by a period of decreasing emissions, and then a subsequent period of increasing emissions. This can be seen from **Figure 1.2**.

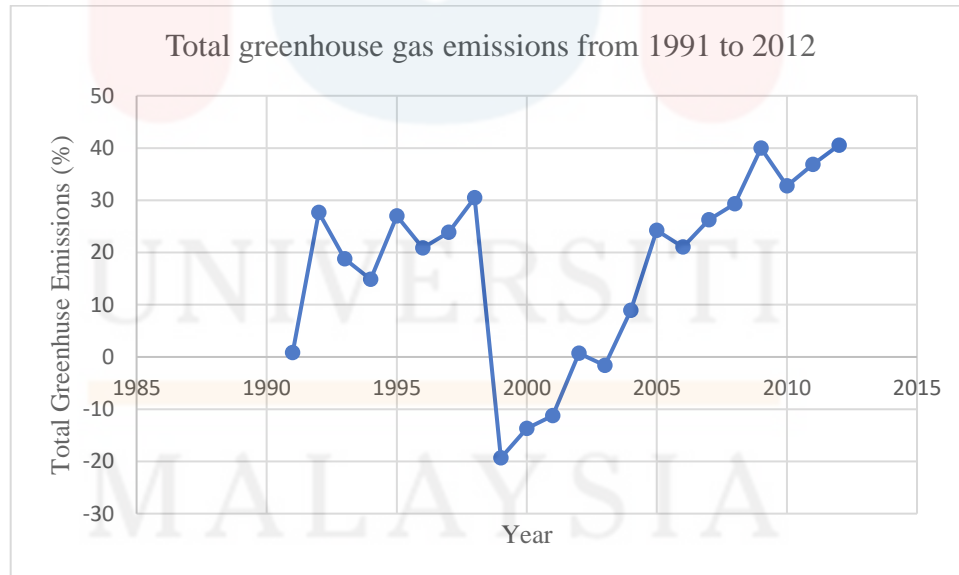


Figure 1.2: Total greenhouse gas emissions from 1990-2012 (Source: The World Bank)

From 1991 to 2002, the percentage change in greenhouse gas emissions shows some fluctuations. There are both positive and negative values during this period, indicating that emissions were varying from year to year. Next, in between 1999 and 2004, there is a consistent pattern of negative values, indicating a decrease in greenhouse gas emissions compared to 1990. This suggests that emissions were decreasing during this time period. Last but not least for 2005 to 2012, the majority of the values are positive, indicating an increase in greenhouse gas emissions compared to 1990. This indicates a trend of increasing emissions during this period.

The increases of greenhouse gases emission are worrisome since it can affect environmental degradation. The research is purposely done to investigate the effect of trading activity in Malaysia on environmental degradation.

1.2 Problem statement

Due to the richness of natural resources, Malaysia engages in a wide range of trading operations. Additionally, the government kept up its support and aid for the expansion of wholesale and retail trade, particularly to encourage Bumiputera participation. Through a number of trust agencies, assistance to Bumiputera participation was carried out with the aim of securing financing facilities, providing company space, and fostering entrepreneurial development.

Retail businesses, like stores, modernized because people's preferences changed. These changes of people behavior encourage these businesses grow more in cities. This shows that trading is happening actively to meet the needs of people and industries.

However, behind the successful of trading activity in the development of a country, there is a dark side where it come with negative adverse impact on the environment. By time, the residual of trading activity has led to environmental degradation and it is getting worse since this activity is done widely.

Trading activity drives the demand for natural resources, leading to greater production of carbon dioxide in order to get the resources. As an example, deforestation produced carbon dioxide due to burning fossil fuel from machinery. According Carbon Dioxide Information Analysis Center (CDIAC), the consumption of fossil fuels and the manufacture of cement have contributed to the atmospheric release of little over 400 billion metric tons of carbon since 1751, with the late 1980s accounting for half of these emissions.

Increased trading activity has amplified pollution levels, particularly in the manufacturing sector. Industrial processes, such as manufacturing textiles and electronics, produce hazardous waste materials that are often disposed of irresponsibly. Moreover, the transportation of goods across long distances leads to carbon emissions and air pollution, further exacerbating the environmental burden. Hence, the purpose of this study is to know how trading activity may affect the environmental degradation.

1.3 Objectives

1. To explore the relationship between trading activity and environmental degradation in Malaysia.
2. To test the existence of an Environmental Kuznets Curve (EKC) trend within Malaysia's trading activities.

1.4 Scope of Study

The scope of study is mainly to inspect on the trading activity and the environmental degradation that has been happening in Malaysia between the year 1980 to 2020 which is in 40 years of timeframe. The main variables that would be discussed in this study is the trading activity in Malaysia and how it is related to the environment degradation. In this research, the data will be analyzed using a software known as Eviews.

1.5 Significance of study

The analysis of how trading activity affects environmental deterioration has significant ramifications for a variety of stakeholders, including the country, its people, and scholars.

As for the nation, this study can contribute to understand the impact of trading activity on environmental degradation helps the nation evaluate the sustainability of its economic development strategies and trade policies. It provides insights into the environmental costs associated with international trade and allows for the formulation of strategies to mitigate negative impacts and enhance environmental performance. The study can inform decision-making processes, helping the nation adopt policies that balance economic growth with environmental protection, leading to more sustainable development.

This study can also benefit the citizens of Malaysia since it can provide few acknowledgements of the environmental consequences of trading activity. This can raise awareness among citizens about the impact of their consumption patterns and lifestyle choices on the environment. The study encourages citizens to make informed decisions,

such as supporting sustainable and eco-friendly products and advocating for responsible trade practices.

Lastly, the study provides researchers with a valuable opportunity to contribute to the existing knowledge on the relationship between trading activity and environmental degradation. It offers insights into the mechanisms through which trading activities affect the environment, contributing to the development of theoretical frameworks and empirical framework for future research. The study helps identify knowledge gaps, guiding researchers to explore specific aspects of trading activity and environmental degradation that require further investigation.

Overall, the study on the effect of trading activity on environmental degradation holds great significance for the nation, citizens, and researchers, contributing to informed decision-making, sustainable policies, responsible consumer choices, and the advancement of knowledge in the field of environmental sustainability.

1.6 Study Area

Malaysia, located in Southeast Asia, serves as an intriguing study area due to its unique geographical, cultural, and environmental characteristics. Known for its diverse ecosystems, including tropical rainforests, pristine coastlines, and rich biodiversity, Malaysia offers a captivating setting for environmental research. The country's strategic position along major trade routes has facilitated economic growth and international trade activities.



Figure 1.3: Map of Malaysia (Source: Google Map)

However, rapid industrialization and urbanization have also raised concerns about environmental degradation and sustainability. By focusing on Malaysia as a study area, researchers have the opportunity to delve into various environmental issues, such as deforestation, pollution, biodiversity conservation, and sustainable development.

Furthermore, Malaysia's cultural diversity and multi-ethnic society provide an interesting backdrop for studying the interactions between human activities, environmental policies, and social dynamics. Investigating Malaysia as a study area offers valuable insights into the complexities of balancing economic development with environmental conservation and offers potential solutions for addressing environmental challenges on a broader scale.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

A literature review is a critical and systematic examination of published research and scholarly articles relevant to a particular topic or research question. In this case, literature reviews of trading activity and environmental degradation will be studied. Literature review involves reviewing and summarizing the existing literature to identify key themes of trading activity and environmental degradation. Other than that, it is easier to identify the concept of trading activity and environmental degradation through previous researchers. Theoretical and empirical literature review will be used to gain more information on the issue.

2.1 Discussing the Concept of Trading Activity and Environmental Degradation

The idea of trading activity and its connection to environmental deterioration are complex and multidimensional. Economic activities involving the exchange of goods, services, or financial assets are referred to as trading activities. Examples include trading on markets or conducting business internationally. Alternatively, the term “environmental

degradation” describes the deterioration of the environment, which includes the depletion of natural resources, pollution, and ecosystem disruption.

2.1.1 Trading Activity

Trading activity serves as the vitality of financial markets, driving economic growth, capital allocation, and wealth creation. Traders, whether individuals or institutions, engage in buying and selling various financial instruments, such as stocks, bonds, commodities, and derivatives, with the aim of profiting from price fluctuations.

Over the past thirty years, the Malaysian economy has grown and undergone structural transformation within the context of a liberal trade and investment regime (Al-Amin, Chamhuri Siwar, Nurul Huda, & Abdul Hamid, 2009). According to Al-Amin, Chamhuri Siwar, Nurul Huda, and Abdul Hamid (2009), the use of power and energy in manufacturing, both directly and indirectly, as well as emissions, result in an influence on the environment.

2.1.1.1 Trade Openness

Trade openness pertains to the present endeavor to enable the flow of goods and services, labour knowledge, funds, and concepts across global borders (Khalid, 2016). According to Singh (2023b), trade and investment can significantly impact the environmental performance of countries, potentially leading to environmental degradation.

2.1.1.2 Gross Domestic Product

The research conducted by Cato, Vigonte, and Abante in 2023 delves into the intricate relationship between international trade activity and gross domestic product (GDP) growth, drawing insights from the dynamics observed in various countries, including the Philippines. As highlighted in the article, the surge in global economic growth over recent decades has been significantly fueled by the expansion of international trade, catalyzed by technological advancements and concerted efforts to mitigate trade barriers. This underscores the pivotal role of trade in shaping GDP trends, with increased trade volumes often correlating with robust GDP growth trajectories.

2.1.1.3 Energy Consumption

Energy consumption in buildings includes tasks like heating, cooling, lighting, and using appliances such as computers and printers (Mohd Ali et al., 2021). Referring to Bonsu and Wang in 2022, the study's findings emphasize that higher trading activity connects with increased energy consumption, increasing economic growth while accelerating environmental degradation. This emphasizes how important it is to implement sustainable policy changes in the energy, trade, and environmental sectors in order to lessen negative effects on the environment.

2.1.2 Environment Degradation

Environmental degradation can occur due to many factors. One of the is through industrial pollution which can be considered as one of the biggest contributors. According to United State Environmental Agency, industry sector emits 6,340 Million Metric Tons of carbon dioxide in 2021. As the quantity of greenhouse gases rises, the buildup of carbon dioxide in the atmosphere causes climate change.

2.1.2.1 Environment Degradation through Industrial pollution

Industrial pollution is pollution with materials used for industrial purposes or those materials that are left over from various industries, and it is one of the most dangerous types of pollution known because of its side effects and toxicity to living organisms (Saeed, 2023). Based on the journal, it is reported that types of pollutant from the industrial that is released which can be harmful to the environment. They are hydrocarbon. Asbestos, heavy metal, and pesticides. These substances may also especially chemical ones, have strong stability and do not decompose naturally, and therefore their effects remain for long periods as quoted by Ibrahim Omar Saeed in 2023.

2.1.2.2 Climate and greenhouses gases

There is an urgent need for solutions as climate change becomes a top priority for both national and international policy. The complex relationship between trade and emission dynamics is deeply ingrained. It affects the place and magnitude of production, shapes consumer preferences, affects emissions from international transportation, and

facilitates the transfer of technologies that may be able to reduce emissions associated with production (Brenton & Chemutai, 2021).

Concerns about the rising carbon dioxide (CO₂) emission have been widely discussed in recent years. Due to its effects on greenhouse effects and eventually extreme global warming, anthropogenic pollution, which is a direct and indirect outcome of domestic households to heavily industrialised activities, has been garnering more attention (Ubaidillah, Decker, Rahim, & Ismail, 2023)

2.2 Theoretical Literature Review on the Relationship between Trading Activity and Environmental Degradation

The review of theoretical literature plays a crucial role in formulating novel and testable hypotheses. It involves identifying existing theories, their interconnections, and the depth of their exploration, laying the groundwork for further investigation. Singh (2023a) reviews the existing theoretical literature on the interconnection between international trade and environmental regulation, examining questions such as the potential for disguised trade barriers through environmental regulations and the consequences of global trade on domestic environmental policy and pollution havens.

2.2.1 The Environment Kuznets Curve Model (EKC)

EKC as one of the pollution-income relationship (PIR), is a negative U-shaped correlation between environmental deterioration and economic progress, proposing that as countries experience economic growth, environmental quality initially declines but gradually becomes greater once a certain income threshold is reached. This model is

invented by Simon Kuznets, who proposed that as economic development advances, income disparity first rises and subsequently declines. Based on Müller-Fürstenberger, Wagner, & Müller (2004), typically, EKC studies look for an inverse U-shape with undesirable by-products of economic activity such as nitrogen oxides (Nox), sulphur dioxide (SO₂), or carbon dioxide (CO₂)

2.2.2 Pollution Haven Hypothesis Theories (PHH)

Critics of trade liberalization contend that lax environmental restrictions in developing and poor countries are the reason behind the concentration of enterprises that produce a lot of pollution in these areas. They claim that consumers in industrialized countries can purchase pollution-intensive products at a reduced cost because environmental resources in underdeveloped countries are undervalued. The Pollution Haven Hypothesis (PHH) refers to the concentration of polluting businesses in less developed countries (Gill, Viswanathan, & Abdul Karim, 2018).

2.3 Empirical Literature Review on the Relationship between Trading Activity and Environmental Degradation

Studies that have been done on the relationship between trading and the environment provide evidence of both positive and uncertain consequences (Bernard & Mandal, 2016). The Pollution Haven Hypothesis and the Environmental Kuznets Curve are important frameworks for examining this relationship in this review. The Pollution Haven Hypothesis warns of worsening environmental conditions due to trade and

investment, especially in the absence of effective laws, while the EKC shows improved environmental quality as economies grow.

2.3.1 The Environment Kuznets Curve Model (EKC)

The effect of global trade on the environment has frequently been the focus of prolonged discussions. The discussions on how commerce affects the environment are important given the growth of global trade and the deterioration of the environment (Bernard & Mandal, 2016). According to Rabbi, Akbar, and Kabir (2015), high economic growth undoubtedly contributes to environmental degradation, but on the other hand, slowing growth might worsen unemployment in a developing nation like Bangladesh.

Previous studies have examined how increased economic activity affects the environment, with researchers highlighting the possible environmental externalities connected to rising global commerce (Frankel, 2009; Levinson, 2009). Increased transportation and production processes associated with increased commerce are associated with higher emissions (Copeland & Taylor, 2004). According to Stern (2004a) and Grossman & Krueger (1991), this viewpoint is consistent with the Environmental Kuznets Curve (EKC) concept, which postulates an initial increase in environmental degradation followed by a subsequent fall as economies mature.

Referring to the Kuznets inverted “U” environmental curve philosophy, efforts to enhance environmental quality increase as national revenue rises. Therefore, it makes sense that trade and growth would lead to increased environmental quality (Kalirajan, Anbumozhi, & Singh, 2010). Results of empirical research on the EKC have been inconsistent. According to Frankel and Rose (2005), there is proof of an EKC for regional

air pollution. The geographic and temporal scope of the inquiry is crucial; despite challenges with model definition, evidence suggests that developing nations are adopting environmental standards for sooner than their predecessors (Stern, 2004a), changing the “turning point.” Lee, Chiu, and Sun (2009) discovered statistically substantial evidence for several cohorts of countries, although they cast doubt on the EKC’s generalizability.

Studies examining the environmental consequences of trading activity within the EKC framework present divergent perspectives. Stern (2004b) casts doubt on the EKC’s robustness by speculating that the relationship might not have a constant trajectory across various contaminants and geographical areas. Notwithstanding these criticisms, a number of studies have discovered empirical evidence in favour of the EKC hypothesis for particular pollutants, such as carbon dioxide emissions (Antweiler, Copeland, & Taylor, 2001).

In the context of global trade, researchers have attempted to clarify the ways in which trading operations impact the EKC trend. Increased trade, according to Antweiler et al. (2001), can help transmit cleaner technology, improving the environment and possibly hastening the achievement of the EKC turning point. This is consistent with the notion that global trade might stimulate favourable environmental effects.

In the trading context, temporal dynamics are central to the EKC discourse. Economic growth, trade openness, and environmental quality are found to have both short- and long-term links, as demonstrated by Nasreen, Anwar, and Ozturk’s (2017) dynamic analysis. Their results emphasize the need of considering how the EKC is changing over a range of timescales.

Another researchers Sulaiman, Azman, and Saboori (2013), investigate the relationship between CO₂ emissions and Malaysian economic growth from 1980-2004 using the Environmental Kuznets Curve, considering energy consumption, exports, and imports. The findings indicate Malaysia's energy consumption significantly contributes to CO₂ emissions, resulting in economic growth and industrial expansion.

2.3.2 Pollution Haven Hypothesis Theories (PHH)

The pollution haven hypothesis, another important argument, contends that dirtier companies have been migrating from the developed to the developing world in order to get around stricter environmental regulations. Trade liberalization will consequently, be troublesome, according to certain scholars. Economic pressures to maintain competitiveness may result in a "race towards the bottom" as countries relax pollution control enforcement or lower environmental requirements in order to maintain their appeal as low-cost manufacturing platforms (Esty, 2001).

The PHH has mixed empirical support, according to the Gill, Viswanathan, & Abdul Karim (2018). While some studies found no evidence of a connection between the strictness of environmental regulations and commerce in commodities that cause pollution, others provided temporary or local evidence in support of the PHH. There are, however, defences of the PHH's implications and theory. These include elements like labour costs, sunk costs, legal frameworks.

2.4 Gap in Literature Review

Based on the articles, there are not much information can be gained regarding trading activity and environment. Also, there is no specific article that solely focus on the effect of environment degradation. This is because most articles focus on the profit obtained from trading activity. Hence, instead of discussing about environment degradation, most author discuss about the policy of trade. In short, the articles are taken from the economist perspective instead of environmentalist perspective.

CHAPTER 3

MATERIALS AND METHODS

3.0 Introduction

This section delves into the process of determining the methodology and economic model that will be employed to examine the correlation between variables. It will be structured into distinct parts. Section 3.1 will center on the theoretical framework, while Section 3.2 will detail the model specification. Following that, Section 3.3 will elaborate on the estimation technique, and finally, Section 3.4 will cover the description of variables and their respective data sources.

3.1 Theoretical framework

The theory used in conducting the research is the Environmental Kuznets Curve (EKC) hypothesis. This method is applied since it explains the relationship of economic growth with environmental degradation. In this case, EKC can assist in monitoring how trading activity can affect environmental degradation. This model suggests that by time, economic growth will expand however there will be depletion in environment degradation. It also suggests that at some point, in the peak, there will be a decrease in environmental degradation since countries will take environmental degradation into consideration. This

is because they want to ensure that despite rapid economic growth, the environment is not tarnished by the activity. This can be simply explained using the graph model introduced by Kuznets.

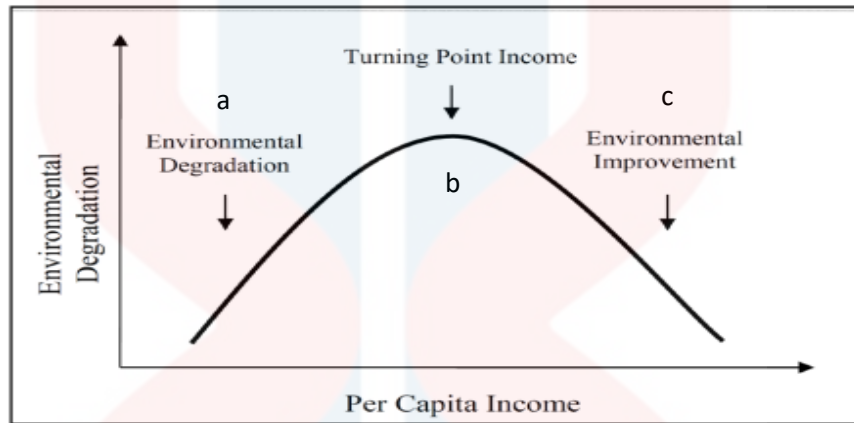


Figure 3.1: The Environmental Kuznets Curve (Source: Google Image)

Based on the graph, it depicts an inverted U-shaped that shows the nexus between environmental degradation and income (per capita). This theory can be used in conducting the research by considering the x-axis representing trade activity, and the y-axis representing an environmental indicator which is pollution emissions in trading activity specifically carbon dioxide.

In general, as trade activity increases environmental degradation also increases. Referring to the graph, the early stage shows increases of environmental degradation as the trading activity increase (a). However, there is a turning point indicate the improvement of environment quality (b). This is because, countries realize the importance of having good quality of environment. The implementation of regulation and sustainable environment practices lead to the turning point in the graph. In short, environment would not be depleting despite having rapid economic in the countries (c).

Below is the basic model of the Environmental Kuznets Curve:

$$\text{CO}_2 = \beta_0 + \beta_1 \text{GDP} + \beta_2 \text{GDP}^2 + \beta_3 Z + \varepsilon \quad (1)$$

In this model, CO₂ stands for carbon dioxide which is the pollutant released from trading activity. GDP is an abbreviation for gross domestic product, which is also known as income, and it functions as an independent variable while Z functions as a control variable. Other environmental pressure factors may be included in the control variable, but they will have no impact on the EKC hypothesis.

3.2 Model Specification

This section is the continuation of the basic model from the Environmental Kuznets Curve. All the variable will be applied in the specific model as shown in Equation 2.

$$\text{CO}_2 = \text{F} (\text{GDP}, \text{GDP}^2, \text{EC}, \text{TOP}) \quad (2)$$

The equation above represents a functional relationship where the Carbon Dioxide (CO₂) is a function (F) of several variables: Gross Domestic Product (GDP), GDP squared (GDP²), Energy consumption (EC), and Trade Openness (TOP). The equation suggests that the Carbon Dioxide (CO₂) emission is influenced by these variables in a functional relationship.

Next, to combine carbon dioxide emission, energy consumption, trade as a percentage of GDP, and GDP per capita into a unified multivariate framework, the regression technique in statistic is used to form another equation as shown below.

$$\text{CO}_2t = \beta_0 + \beta_1\text{GDP}t + \beta_2\text{GDP}2t + \beta_3\text{Ect} + \beta_4\text{TOP}t + \epsilon t \quad (3)$$

Where $\beta_0 - \beta_4$ are parameters of equation (3) and ϵt is stochastic error term.

Lastly, t is the time period covered by the study.

3.3 Estimation Method

Since many years ago, researchers have utilized the autoregressive distributed lag (ARDL) model to examine the relationship between variables using time series with a single equation. The ARDL model is one of the econometric literature's most broadly applicable dynamic unrestricted models. The dependent variable in this model is expressed by the lag, current, and own lag values of independent variables (Abonazel & Elnabawy, 2020).

For many years, the ARDL model has been a mainstay in econometrics. It was first extended by Pesaran and Shin (1999) and then further improved by Pesaran et al. (2001). Nonetheless, it is notable that its use as a method for examining the cointegration of economic variables has recently become more prominent.

According to Emeka and Kelvin (2016), the word "cointegration" in econometrics refers to the existence of a long-run equilibrium between economic variables that

converges with time. They go on to say that among the most current methods for looking at the dynamic and equilibrium interactions between dependent and independent variables, the ARDL approach stands out.

To test for cointegration links between the variables of interest, the study employed the ARDL model's cointegration technique in a recursive style (Abonazel & Elnabawy, 2020). By using the recursive style, there are several advantages for testing cointegration links between variables of interest. These advantages include:

1. The ARDL model allows for the inclusion of variables with different orders of integration. As an example, $I[0]$ – stationary, $I(1)$ – integrated of order 1, or mixed. This flexibility is advantageous because it accommodates variables that have been differenced to achieve stationarity or variables that are already stationary.
2. The ARDL model enables the estimation of both short-run and long-run coefficients simultaneously.
3. By considering both short-run and long-run effects, the ARDL model captures the dynamic relationship between variables over time. It allows for the examination of how variables respond to short-term shocks and how they converge towards their long-run equilibrium.
4. The ARDL model is particularly useful when working with limited data or small time series.

3.4 Variable Description & Data Sources

Table 3.1: Variable description

Variables	Description	Measurement
CO ₂	Carbon dioxide emission	The level of total carbon dioxide emitted during trade activity is used to calculate the EF.
GDP	GDP annual growth rate	GDP growth rate (%)
EC	Energy Consumption	% of total energy consumption
TOP	Trade as a % of GDP	Trade can be quantified as the combined value of exports and imports of goods and services, typically expressed as a percentage of the Gross Domestic Product (GDP).

3.5 Research Flowchart

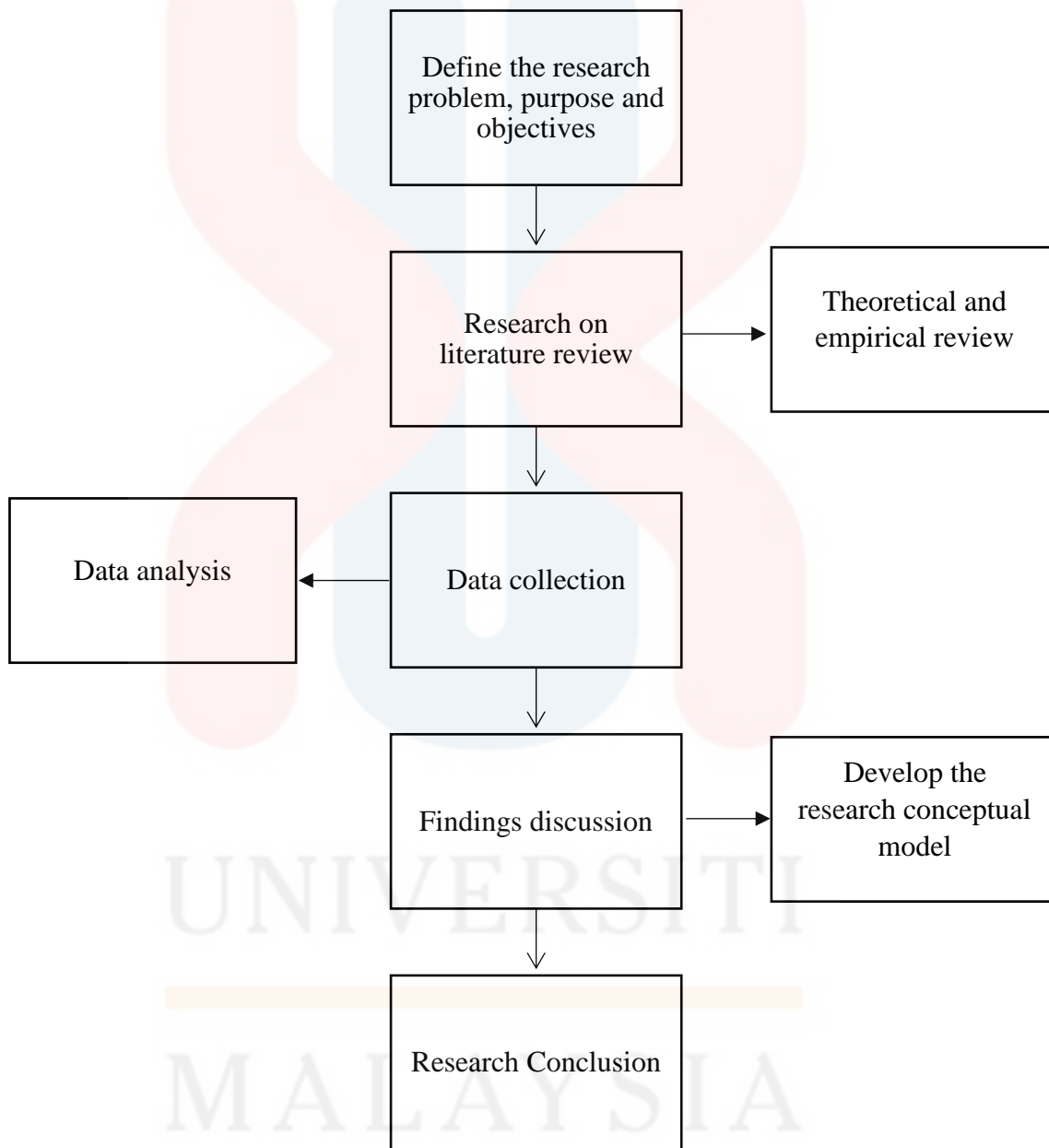


Figure 3.2: Research flowchart

CHAPTER 4

RESULT AND DISCUSSION

4.0 Introduction

Chapter 4 delves into the results and discussions, unfolding the findings through a series of important analyses. Beginning with subsection 4.1 that explore summary statistics which can provide a foundational understanding of data tendencies. Subsection 4.2 presents the correlation matrix, which illustrates the relationship between the variables. The results of the unit root test provide information on variable stationarity in Subsection 4.3. Cointegration is examined in Subsection 4.4, revealing enduring, steady linkages. ARDL tests are explored in Subsection 4.5, offering information on both short- and long-term dynamics. In conclusion, the reliability of our model is confirmed by looking at ARDL diagnostic tests in Subsection 4.6. This chapter presents a methodical event that improves the comprehension of the facts and adds to a sophisticated discourse on the findings of the investigation.

4.1 Summary of Descriptive Statistics

This section will explain about summary statistics that provide a concise overview of characteristics within a dataset (**Table 4.1**), including measures like mean, median, standard deviation, minimum, and maximum values. They offer a snapshot of the central tendency, dispersion, and shape of the data distribution. The importance of summary statistics lies in their ability to simplify complex data, making it more understandable and facilitating comparisons between different datasets.

Table 4.1: Descriptive statistics.

Variable	Observations	Mean	Std. Dev.	Median	Minimum	Maximum	Jarque- Bera	Probability
TOP	41	11.64061	19.55749	6.869309	-27.33585	86.48692	43.18957	0.000000
GDP	41	6516.652	2387.195	6461.981	3159.737	11114.54	2.268707	0.321630
EC	41	2023.335	719.0846	7.655801	899.9720	2930.848	3.638720	0.162129
CO ₂	41	5.300244	2.044471	5.504000	2.121000	8.154000	3.406290	0.182110

Note: TOP is trade openness, GDP is gross domestic P\product, EC is energy consumption, and CO₂ is carbon dioxide emissions

This section will explain about summary statistics that provide a concise overview of characteristics within a dataset, including measures like mean, median, standard deviation, minimum, and maximum values. They offer a snapshot of the central tendency, dispersion, and shape of the data distribution. The importance of summary statistics lies in their ability to simplify complex data, making

it more understandable and facilitating comparisons between different datasets.

At a mean value of 11.64061, the trade openness ratio variable (TOP) indicates a positive trade balance on average. The 19.55749 standard deviation indicates a high degree of unpredictability in the trade balance. There may occasionally be a negative trade balance (imports surpassing exports), as indicated by the minimum value of -27.33585. 86.48692, the greatest figure, indicates a sizable positive cut balance. The p-value of 0.000000 for the Jarque-Bera test indicates that the distribution of TOP is not normal.

GDP, or average economic production per capita, has a mean of 6516.652 for the sample. The variability in economic prosperity across data is reflected in the 2387.195 standard deviation. The range of per capita GDP is shown by the lowest and maximum figures, which vary from 3159.737 to 11114.54. For GDP, the Jarque-Bera test yields a p-value of 0.321630, which suggests a reasonably normal distribution.

The average energy consumption in the sample is reflected in the EC, which measures energy usage, with a mean of 2023.335. The 719.0846 standard deviation indicates that energy use varies amongst observations. The range of energy usage is shown by the smallest value of 899.9720 and the maximum value of 2930.848. With a p-value of 0.162129, the Jarque-Bera test indicates that the EC distribution is roughly normal.

At a mean of 5.300244, CO₂ represents the sample's average carbon dioxide emissions. The variation in carbon emissions over different observations is shown in the standard deviation of 2.044471. Carbon dioxide emissions range from 2.121 to 8.154, the lowest and maximum values. With a p-value of 0.182110, the Jarque-Bera test indicates that the CO₂ distribution is roughly typical

4.2 Correlation Matrix

Table 4.2: Correlation matrix results

	TOP	GDP	EC
TOP	1	0.387894	0.417223
GDP	0.387894	1	0.970873
EC	0.417223	0.970873	1

Note: TOP is the trade openness, GDP is the gross domestic product, EC is the energy consumption. CO₂ is not included since it is dependent variable.

The correlations between the variables are illustrated by the correlation matrix in **Table 4.2**. Starting with TOP, it exhibits a moderate positive correlation with both GDP and EC, with correlation coefficients of 0.387894 and 0.417223, respectively. This implies that as trade openness activities increase, there is a tendency for both GDP per capita and energy use to also rise, though the relationships are not exceptionally strong.

Moving on to GDP, it demonstrates a positive correlation of 0.387894 with TOP and a remarkably strong positive correlation of 0.970873 with EC. The strong correlation between GDP and EC suggests a robust association between higher GDP per capita and increased energy usage. This could indicate that wealthier nations tend to consume more energy resources.

Lastly, EC, representing Energy Consumption, displays positive correlations of 0.417223 with TOP and an even higher correlation of 0.970873 with GDP. This indicates a substantial link between energy consumption and both trade openness activities and GDP per capita. The exceptionally high correlation between EC and GDP reinforces the idea that economic prosperity is closely tied to energy utilization

4.3 Unit Root Test

Table 4.3: Unit root test

Variable	Level				First Difference			
	ADF		PP		ADF		PP	
	Constant	Constant & trend	Constant	Constant & trend	Constant	Constant & trend	Constant	Constant & trend
CO ₂	-0.796 (0.8094)	-2.6387 (0.2663)	-0.7409 (0.8246)	-2.6387 (0.2663)	-6.7810*** (0.0000)	-6.7030*** (0.000)	-7.3962*** (0.0000)	-7.3728*** (0.0000)
TOP	-4.7775*** (0.0004)	-3.9460 (0.0198)	-4.9300 (0.0002)	-5.3444 (0.0005)	-7.3213*** (0.0000)	-7.2830*** (0.0000)	-11.5129*** (0.0000)	-11.4506*** (0.0000)
EC	-0.9421 (0.7642)	-2.0641 (0.5493)	-1.0114 (0.7401)	-2.1264 (0.5159)	-6.6288*** (0.0000)	-6.6207*** (0.0000)	-6.9085*** (0.0000)	-7.1202*** (0.0000)
GDP	0.1552 (0.9661)	-2.5391 (0.3088)	0.1467 (0.9655)	-2.5391 (0.3088)	-4.7330*** (0.0004)	-4.5880*** (0.0038)	-4.7371*** (0.0004)	-4.4476*** (0.0055)

Note: CO₂ is the carbon dioxide emission, TOP is trade openness, EC is energy consumption, and GDP is gross domestic product. ADF is the Augmented Dickey-Fuller while PP is Phillip Perron, and the figure in brackets (...) represents the probability of the variables. ***, **, * indicate statistical significance at 1%, 5%, and 10% levels.

The unit root test results, conducted using both Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests for levels and first differences, offer insights into the stationarity of the variables. Referring to Herranz in 2017, he stated that unit root tests deal with the alternative hypothesis of a stationary (or trend stationary) time series and the null hypothesis of a unit root. He also highlighted that

in order to be sure that our time series are most likely stationary processes, one must test unit roots beforehand. This is because, using unit roots in linear regression studies can result in erroneous regressions. Unit root test emphasizes the importance of assessing stationarity against the unit root hypothesis and conducting both types of tests to ensure a comprehensive evaluation of the data (Bierens & Guo, 1993).

For CO₂ at the level, the ADF and PP test statistics are -0.7960 and 0.8094, respectively, both exceeding critical values, indicating non-rejection of the null hypothesis of a unit root. The non-significant ADF and PP test statistics suggest that CO₂ is non-stationary at the level, indicating a presence of a unit root. This could be attributed to a long-term trend or structural change. In the first difference, both tests show highly significant results with statistics of -6.7810 and -6.7030, suggesting that after differencing, the variable becomes stationary. This is suggesting that fluctuations or trends have been removed, and the data is now more suitable for analysis.

Moving on to the next variable which is TOP, the level, both ADF and PP statistics are highly significant at -4.7775 and 0.0004, indicating that TOP is non-stationary. This could be due to a long-term trend or structural changes. In the first difference, both tests continue to show strong significance, supporting the stationarity of the differenced TOP variable.

Similar to CO₂, at the level, EC shows non-stationarity with ADF and PP statistics of -0.9421 and 0.7642. In the first difference, the tests provide highly significant results, indicating that differencing makes the variable stationary.

Lastly, at the level, GDP exhibits non-stationarity with ADF and PP statistics of 0.1552 and 0.9661. Differencing the GDP variable results in stationarity, supported by significant ADF and PP statistics of -4.7330 and -4.5880.

In summary, the unit root tests suggest that the first differences of all variables (CO₂, TOP, EC, GDP) are stationary, indicating that these variables become more suitable for time-series analysis after differencing. The non-stationarity observed at the level for some variables underscores the importance of differencing to achieve stationarity in time series data.

4.4 Cointegration Test (Bound Test)

Table 4.4: Cointegration test results

Model	F-Statistics	Lag	Level of Significance	ARDL Bound test critical values (Unrestricted intercept and no trend)	
				I (0)	I (1)
$f(\ln LCO_2 / \ln LGDP, \ln LEC, \ln LTOP)$	9.289769	4	1%	2.525	3.56
			5%	3.058	4.223
			10%	4.28	5.84

n=35

Note: $\ln LCO_2$ is the logarithm of adjusted carbon dioxide emissions, $\ln LGDP$, $\ln LEC$ and $\ln LTOP$ is the logarithm of adjusted gross domestic product, energy consumption, and trade openness respectively.

The cointegration test results are presented in **Table 4.4** using the ARDL (Autoregressive Distributed Lag) bound test critical values. The ARDL bounds testing approach helps identify if variables have a long-term relationship. If such a relationship exists, the approach also facilitates the development of a model for estimating short-term coefficients through error correction. (Yakubu, Manu, & Bala, 2015)

The model under consideration includes the variables $\ln LCO_2$, $\ln LGDP$, $\ln LEC$, and $\ln LTOP$. The F-Statistics value is 9.289769 with 4 lags, indicating the test's statistical significance. To evaluate cointegration, the critical values at various significance levels are provided.

For a 1% level of significance, the critical value is 2.525; for a 5% level, it is 3.058, and for a 10% level, it is 4.28. The values of I(0) and I(1) are also presented, indicating the critical values for the presence of a cointegrating relationship at 0% and 1% levels. These critical values serve as benchmarks to assess whether the variables are cointegrated.

If the F-statistic surpasses the upper bound, it indicates the presence of a long-run level relationship among the variables. Conversely, if it falls below the lower bound, there is no long-run level relationship among the variables (Yakubu, Manu, & Bala, 2015).

Based on the result (**Table 4.4**) obtained from data analysis, the F-statistic (9.289769) exceeds the critical value corresponding to the desired level of significance (1%, 5%, or 10%), it suggests that a long-run level relationship exists among the variables under consideration. This suggests that changes in the variables (lnLCO₂, lnLGDP, lnLEC, lnLTOP) have a significant long-term impact on the model's outcome, as indicated by the ARDL bound test critical values.

4.5 ARDL Coefficients/ Long-Run and Error Correction Method (ECM) ARDL

Table 4.5: ARDL test result

Variable	Coefficient	T-stat	P-Value
<i>CO₂=Dependant Variable</i>			
<i>Long-run</i>			
Constant	-37.114***	-3.357	0.002
lnEC	0.001	0.493	0.625
lnGDP	0.427**	2.153	0.040
lnGDP ²	7.531***	2.963	0.006
lnTOP	-0.397***	-2.957	0.006
<i>Short run</i>			
$\Delta \ln \text{LNTOP}$	0.001	0.483	0.632
$\Delta \ln \text{LNEC}$	0.454**	2.159	0.039
$\Delta \ln \text{LNGDP}$	8.009***	3.449	0.001
$\Delta \ln \text{LNGDP}^2$	-0.422***	-3.386	0.002

Note: CO₂ is the dependent variable so it won't be included in this test. Therefore, lnEC, lnGDP, and, lnTOP is the logarithm of energy consumption, gross domestic product, and trade openness respectively.

In this regression analysis, the relationship between the dependent variable, CO₂, and various independent variables are determined. The relevance of these factors is shown by the coefficients, T-statistics, and P-values. The research highlights several facets of the relationship by differentiating between the long- and short-term effects.

The "long run" refers to a period of time encompassing the sustained effects and relationships between the variables under investigation (Ifa & Guetat, 2021). Specifically, this study aims to analyze the long-run effects of carbon dioxide emission, energy consumption, gross domestic product, trade openness in Malaysia over the span of 1980-2020. In the long run, a positive coefficient means that as the independent variable increases, the dependent variable also increases over time. Conversely, a negative coefficient indicates that as the independent variable increases, the dependent variable decreases over time.

In the long run, the constant term (-37.114) represents the starting point level of CO₂ when all independent variables are zero. With a P-value of 0.625 and a T-status of 0.493, the coefficient for lnEC is 0.001, showing a negligible effect. Meanwhile, lnGDP and lnGDP2 show stronger effects, with coefficients of 0.531 and 0.427, respectively. The quadratic term (lnGDP2) suggests a nonlinear relationship between CO₂ and the logarithm of GDP per capita, indicating a positive correlation between the two. Furthermore, there is a negative correlation between lnTOP and CO₂ (-0.397), suggesting that a rise in lnTOP is linked to a long-term drop in CO₂ levels.

The "short run" refers to a period where adjustments in variables like Specifically, this study aims to analyze the long-run effects of carbon dioxide emission, energy consumption, gross domestic product, trade openness occur relatively quickly (Ifa & Guetat, 2021). The symbol Δ (change) is used to represent short-run dynamics because it signifies alterations or fluctuations in variables over a relatively brief period.

The variables $\Delta \ln \text{LNTOP}$, $\Delta \ln \text{LNEC}$, $\Delta \ln \text{LNGDP}$, and $\Delta \ln \text{LNGDP}^2$ depict the short-term variations in their corresponding amounts. Notably, $\Delta \ln \text{LNGDP}^2$ has a

considerable negative influence on CO₂ while $\Delta \ln \text{LNGDP}$ has a big positive impact. This implies that short-term variations in GDP per capita, which have a nonlinear component indicated in the quadratic term, have a significant impact on CO₂ levels.

The results of both the short- and long-term analyses offer a thorough grasp of the variables' relationship. The quick response of CO₂ to changes in $\ln \text{LNTOP}$, $\ln \text{LNEC}$, $\ln \text{LNGDP}$, and $\ln \text{LNGDP}^2$ is demonstrated by short-run effects, whilst long-run effects illustrate overall trends and long-lasting implications. The combined effect of these perspectives facilitates the development of a sophisticated comprehension of the intricate relationship among the variables over various time intervals, hence enhancing the reliability of the regression outcomes.

Overall, the results offer empirical evidence in supporting the existence of an EKC, in which trade activity, economic growth, and environmental damage are correlated along an upward curve. The quadratic term indicates a turning point where the rate of environmental degradation drops downward, potentially indicating an increase towards sustainability.

4.6 Diagnostic Test

The diagnostic test outcomes are generalized as follows:

Table 4.6: The result of ARDL diagnostic test

Test Statistics	F-statistic
Breusch-Godfrey Serial Correlation	0.551763 (0.5828)
Breusch-Pagan-Godfrey Heteroskedasticity	0.909462 (0.4895)
Model specification Ramsey RESET	0.342253 (0.536)
Normality	1.611498 (0.446753)

Note: The figure in brackets (...) represents the probability of the variables

A thorough understanding of the validity and reliability of the regression model can be obtained by looking at its diagnostic tests. A non-significant p-value of 0.5828 from the Breusch-Godfrey Serial Correlation Test indicates that there is no significant serial correlation in the residuals. This implies that the assumption of observational independence is fairly satisfied, strengthening the model's robustness. Similarly, there is no significant evidence of non-constant variance in the residuals, according to the Breusch-Pagan-Godfrey Heteroskedasticity Test, which produces a p-value of 0.4895. The computed coefficients' accuracy and stability are enhanced by the model's adherence to the homoskedasticity condition.

Furthermore, the Model Specification Ramsey RESET Test confirms that the proposed model adequately captures the relationship between variables, with a p-value of 0.536. This implies that there aren't any significant nonlinearities missing, confirming the accuracy of the model's specification. Furthermore, a p-value of 0.446753 from the residuals' Normality Test indicates that there is no discernible deviation from a normal distribution. This lends credibility to the assumption of normalcy, which is essential to drawing reliable statistical conclusions. The regression model gains credibility from the

accumulated outcomes of these diagnostic tests, boosting trust in its capacity to identify and explain the underlying patterns in the data.

As for the CUSUM and CUSUM-of-squares tests are within the 5% critical limits, indicating that the recursive residuals are fine in terms of mean and variance.

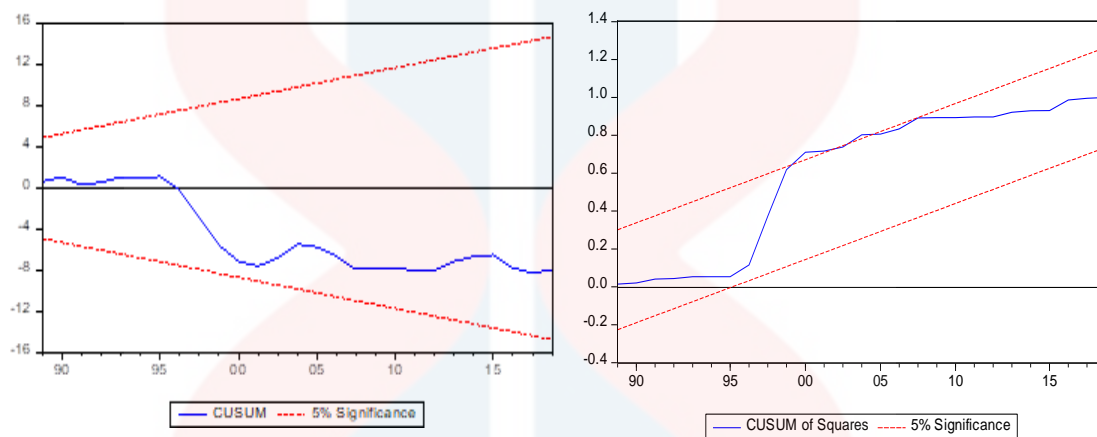


Figure 4.1: CUSUM and CUSUM of square

CONCLUSION AND RECOMMENDATION

5.0 Introduction

This chapter described the study's conclusions and their implications for policy in Section 5.2, while Section 5.3 lists the study's limitations and suggests more research.

5.1 Conclusion & Implication

In conclusion, this study has systematically explored the complex relationship between Malaysia's trading activity and environmental degradation throughout the period from 1980 to 2020. Trade, which is defined as the international exchange of goods and services, has been a major factor in Malaysia's growth in economy. The observed coefficients in **Table 4.5** provide compelling evidence supporting the presence of the Environmental Kuznets Curve within the trading activities of Malaysia. The positive and significant impact of GDP, coupled with the negative effect of GDP², implies that as Malaysia's economy grows through trading activities, there exists a turning point beyond which environmental quality improves. These findings contribute to the growing body of literature affirming the applicability of the EKC framework to diverse economic contexts, emphasizing the potential for sustainable development through responsible trade practices. The implications of these findings call for careful policy considerations,

emphasizing the need to balance economic growth with environmental sustainability, explore energy efficiency measures, and engage in comprehensive planning that adapts to short-term dynamics. The unexpected findings related to energy consumption also highlight the importance of further investigation and exploration of additional factors influencing carbon emissions to enhance the robustness of policy conclusions. Ultimately, the project contributes valuable insights that can inform more nuanced and context-specific policies aimed at achieving sustainable development goals while addressing environmental challenges.

5.2 Recommendation & Limitation

In light of our exploration into Malaysia's trading activities and their environmental ramifications, several recommendations emerge to steer the nation towards a more sustainable and balanced future. Firstly, aligning trade policies with sustainable development goals can amplify positive impacts, urging policymakers to incorporate environmental considerations into trade agreements. Secondly, targeted programs promoting energy efficiency across sectors could contribute to a more sustainable energy consumption pattern. Encouraging investments in renewable resources stands as a pivotal recommendation, diversifying the energy mix and reducing carbon emissions. Additionally, establishing a robust monitoring system for environmental indicators can provide real-time insights for timely interventions. However, our study is not without limitations. Data constraints and assumptions about causality should be acknowledged, and the economic complexity and temporal scope of the study warrant consideration in future research and policy formulations.

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APPENDIX A

Preliminary Test

Descriptive Statistics

	TOP	GDP	CO ₂	EC
Mean	11.64061	6516.652	5.300244	2023.335
Median	6.869309	6461.981	5.504000	2130.698
Maximum	86.48692	11114.54	8.154000	2930.848
Minimum	-27.33585	3159.737	2.121000	899.9720
Std. Dev.	19.55749	2387.195	2.044471	719.0846
Skewness	1.549961	0.254288	-0.223166	-0.198032
Kurtosis	6.958811	1.965895	1.660331	1.595324
Jarque-Bera	43.18957	2.268707	3.406290	3.638720
Probability	0.000000	0.321630	0.182110	0.162129
Sum	477.2649	267182.7	217.3100	82956.73
Sum Sq. Dev.	15299.81	2.28E+08	167.1945	20683306
Observations	41	41	41	41

Correlation Matrix

	TOP	GDP	CO ₂	EC
TOP	1	0.3878938240	0.3883418511	0.4172228808
GDP	0.3878938240	1	0.9717255389	0.9708730730
CO ₂	0.3883418511	0.9717255389	1	0.9897778962
EC	0.4172228808	0.9708730730	0.9897778962	1

	LNTOP	LNGDPPC	LNCO	LNEC
LNTOP	1	0.111375136	0.108570084	0.101434584
LNGDPPC	0.111375136	1	0.979773105	0.984892760
LNCO	0.108570084	0.979773105	1	0.990398817
LNEC	0.101434584	0.984892760	0.990398817	1

APPENDIX B

Cointegration Bound Test

F-statistic	9.289769	10%	2.2	3.09
k	4	5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37
Actual Sample Size	33		Finite Sample: n=35	
		10%	2.46	3.46
		5%	2.947	4.088
		1%	4.093	5.532
			Finite Sample: n=30	
		10%	2.525	3.56
		5%	3.058	4.223
		1%	4.28	5.84

APPENDIX C

Long-Run & Short Run Bound Test

ARDL Long Run Form and Bounds Test
 Dependent Variable: D(LNCO)
 Selected Model: ARDL(1, 0, 0, 0, 0)
 Case 2: Restricted Constant and No Trend
 Date: 12/20/23 Time: 23:22
 Sample: 1980 2020
 Included observations: 33

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-37.11434	11.05445	-3.357412	0.0024
LNCO(-1)*	-0.940321	0.170129	-5.527114	0.0000
LNTOP**	0.001061	0.002151	0.493365	0.6257
LNEC**	0.427711	0.198581	2.153843	0.0403
LNGDPPC**	7.531941	2.541491	2.963591	0.0063
LNGDPPC2**	-0.397753	0.134485	-2.957607	0.0064

* 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.
LNTOP	0.001129	0.002333	0.483774	0.6324
LNEC	0.454857	0.210657	2.159227	0.0399
LNGDPPC	8.009972	2.322336	3.449101	0.0019
LNGDPPC2	-0.422997	0.124899	-3.386719	0.0022
C	-39.46988	9.611494	-4.106529	0.0003

$$EC = LNCO - (0.0011*LNTOP + 0.4549*LNEC + 8.0100*LNGDPPC - 0.4230 *LNGDPPC2 - 39.4699)$$

APPENDIX D

Unit Root Test

ADF (LEVEL AND INTERCEPT) OF CO₂

Null Hypothesis: CO₂ has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.795965	0.8094
Test critical values: 1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

*MacKinnon (1996) one-sided p-values.

ADF OF CO₂ (LEVEL, TREND, INTERCEPT)

Null Hypothesis: CO₂ has a unit root
 Exogenous: Constant, Linear Trend
 Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.638684	0.2663
Test critical values: 1% level	-4.205004	
5% level	-3.526609	
10% level	-3.194611	

*MacKinnon (1996) one-sided p-values.

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ADF (1ST DIFFERENCE AND INTERCEPT) OF CO₂

Null Hypothesis: D(CO₂) has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.780995	0.0000
Test critical values:		
1% level	-3.610453	
5% level	-2.938987	
10% level	-2.607932	

ADF (1ST DIFFERENCE, TREND AND INTERCEPT) OF CO₂

Null Hypothesis: D(CO₂) has a unit root
 Exogenous: Constant, Linear Trend
 Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.703045	0.0000
Test critical values:		
1% level	-4.211868	
5% level	-3.529758	
10% level	-3.196411	

*MacKinnon (1996) one-sided p-values.



PP (LEVEL AND INTERCEPT) OF CO₂

Null Hypothesis: CO₂ has a unit root
 Exogenous: Constant
 Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-0.740932	0.8246
Test critical values:		
1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.118931
HAC corrected variance (Bartlett kernel)	0.045644

PP OF CO₂ (LEVEL, TREND AND INTERCEPT)

Null Hypothesis: CO₂ has a unit root
 Exogenous: Constant, Linear Trend
 Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.638684	0.2663
Test critical values:		
1% level	-4.205004	
5% level	-3.526609	
10% level	-3.194611	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.101537
HAC corrected variance (Bartlett kernel)	0.101537

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PP (1ST DIFFERENCE AND INTERCEPT) OF CO₂

Null Hypothesis: D(CO₂) has a unit root
 Exogenous: Constant
 Bandwidth: 7 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-7.396158	0.0000
Test critical values:		
1% level	-3.610453	
5% level	-2.938987	
10% level	-2.607932	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.122464
HAC corrected variance (Bartlett kernel)	0.060854

PP (1ST DIFFERENCE, TREND AND INTERCEPT) OF CO₂

Null Hypothesis: D(CO₂) has a unit root
 Exogenous: Constant, Linear Trend
 Bandwidth: 7 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-7.372823	0.0000
Test critical values:		
1% level	-4.211868	
5% level	-3.529758	
10% level	-3.196411	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.122141
HAC corrected variance (Bartlett kernel)	0.057356

ADF (LEVEL AND INTERCEPT) OF TOP

Null Hypothesis: TOP has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.777539	0.0004
Test critical values: 1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

*MacKinnon (1996) one-sided p-values.

ADF (LEVEL, TREND AND INTERCEPT) OF TOP

Null Hypothesis: TOP has a unit root
 Exogenous: Constant, Linear Trend
 Lag Length: 3 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-3.945979	0.0198
Test critical values: 1% level	-4.226815	
5% level	-3.536601	
10% level	-3.200320	

*MacKinnon (1996) one-sided p-values.

ADF (1ST DIFFERENCE AND INTERCEPT) OF TOP

Null Hypothesis: D(TOP) has a unit root
 Exogenous: Constant
 Lag Length: 1 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.321352	0.0000
Test critical values: 1% level	-3.615588	
5% level	-2.941145	
10% level	-2.609066	

*MacKinnon (1996) one-sided p-values.

ADF (1ST DIFFERENCE, TREND AND INTERCEPT) OF TOP

Null Hypothesis: D(TOP) has a unit root
 Exogenous: Constant, Linear Trend
 Lag Length: 1 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.282953	0.0000
Test critical values:		
1% level	-4.219126	
5% level	-3.533083	
10% level	-3.198312	

*MacKinnon (1996) one-sided p-values.

PP (LEVEL AND INTERCEPT) OF TOP

Null Hypothesis: TOP has a unit root
 Exogenous: Constant
 Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-4.929591	0.0002
Test critical values:		
1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	359.1378
HAC corrected variance (Bartlett kernel)	431.7306

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PP (LEVEL, TREND AND INTERCEPT) OF TOP

Null Hypothesis: TOP has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-5.344354	0.0005
Test critical values: 1% level	-4.205004	
5% level	-3.526609	
10% level	-3.194611	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	326.3673
HAC corrected variance (Bartlett kernel)	352.5641

PP (1ST DIFFERENCE AND INTERCEPT) OF TOP

Null Hypothesis: D(TOP) has a unit root

Exogenous: Constant

Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-11.51289	0.0000
Test critical values: 1% level	-3.610453	
5% level	-2.938987	
10% level	-2.607932	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	434.3583
HAC corrected variance (Bartlett kernel)	325.7865

PP (1ST DIFFERENCE, TREND AND INTERCEPT) OF TOP

Null Hypothesis: D(TOP) has a unit root
 Exogenous: Constant, Linear Trend
 Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-11.45059	0.0000
Test critical values:		
1% level	-4.211868	
5% level	-3.529758	
10% level	-3.196411	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	429.6735
HAC corrected variance (Bartlett kernel)	320.0478

ADF (LEVEL AND INTERCEPT) OF EC

Null Hypothesis: EC has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.942148	0.7642
Test critical values:		
1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

*MacKinnon (1996) one-sided p-values.



ADF (LEVEL, TREND AND INTERCEPT) OF EC

Null Hypothesis: EC has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.942148	0.7642
Test critical values: 1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

*MacKinnon (1996) one-sided p-values.

ADF (1ST DIFFERENCE AND INTERCEPT) OF EC

Null Hypothesis: D(EC) has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.628802	0.0000
Test critical values: 1% level	-3.610453	
5% level	-2.938987	
10% level	-2.607932	

*MacKinnon (1996) one-sided p-values.

ADF (1ST DIFFERENCE, TREND AND INTERCEPT) OF EC

Null Hypothesis: D(EC) has a unit root
 Exogenous: Constant, Linear Trend
 Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.620682	0.0000
Test critical values: 1% level	-4.211868	
5% level	-3.529758	
10% level	-3.196411	

*MacKinnon (1996) one-sided p-values.

PP (LEVEL AND INTERCEPT) OF EC

Null Hypothesis: EC has a unit root
 Exogenous: Constant
 Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-1.011402	0.7401
Test critical values: 1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	
*MacKinnon (1996) one-sided p-values.		
Residual variance (no correction)		9197.547
HAC corrected variance (Bartlett kernel)		4996.512

PP (LEVEL, TREND AND INTERCEPT) OF EC

Null Hypothesis: EC has a unit root
 Exogenous: Constant, Linear Trend
 Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.126432	0.5159
Test critical values: 1% level	-4.205004	
5% level	-3.526609	
10% level	-3.194611	
*MacKinnon (1996) one-sided p-values.		
Residual variance (no correction)		8358.102
HAC corrected variance (Bartlett kernel)		8732.041

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PP (1ST DIFFERENCE AND INTERCEPT) OF EC

Null Hypothesis: D(EC) has a unit root
 Exogenous: Constant
 Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-6.908474	0.0000
Test critical values:		
1% level	-3.610453	
5% level	-2.938987	
10% level	-2.607932	
*MacKinnon (1996) one-sided p-values.		
Residual variance (no correction)		9570.735
HAC corrected variance (Bartlett kernel)		5960.066

PP (1ST DIFFERENCE, TREND AND INTERCEPT) OF EC

Null Hypothesis: D(EC) has a unit root
 Exogenous: Constant, Linear Trend
 Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-7.120246	0.0000
Test critical values:		
1% level	-4.211868	
5% level	-3.529758	
10% level	-3.196411	
*MacKinnon (1996) one-sided p-values.		
Residual variance (no correction)		9437.012
HAC corrected variance (Bartlett kernel)		4878.398

ADF (LEVEL AND INTERCEPT) OF GDP

Null Hypothesis: GDP has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	0.155161	0.9661
Test critical values: 1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

*MacKinnon (1996) one-sided p-values.

ADF (LEVEL, TREND AND INTERCEPT) OF GDP

Null Hypothesis: GDP has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.539064	0.3088
Test critical values: 1% level	-4.205004	
5% level	-3.526609	
10% level	-3.194611	

*MacKinnon (1996) one-sided p-values.

ADF (1ST DIFFERENCE AND INTERCEPT) OF GDP

Null Hypothesis: D(GDP) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.732957	0.0004
Test critical values: 1% level	-3.610453	
5% level	-2.938987	
10% level	-2.607932	

*MacKinnon (1996) one-sided p-values.

ADF (1ST DIFFERENCE, TREND AND INTERCEPT) OF GDP

Null Hypothesis: D(GDP) has a unit root
 Exogenous: Constant, Linear Trend
 Lag Length: 0 (Automatic - based on SIC, maxlag=4)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.587956	0.0038
Test critical values: 1% level	-4.211868	
5% level	-3.529758	
10% level	-3.196411	

*MacKinnon (1996) one-sided p-values.

PP (LEVEL AND INTERCEPT) OF GDP

Null Hypothesis: GDP has a unit root
 Exogenous: Constant
 Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	0.146713	0.9655
Test critical values: 1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	63303.51
HAC corrected variance (Bartlett kernel)	64582.83



PP (LEVEL, TREND AND INTERCEPT) OF GDP

Null Hypothesis: GDP has a unit root
 Exogenous: Constant, Linear Trend
 Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.539064	0.3088
Test critical values:		
1% level	-4.205004	
5% level	-3.526609	
10% level	-3.194611	
*MacKinnon (1996) one-sided p-values.		
Residual variance (no correction)		53523.69
HAC corrected variance (Bartlett kernel)		53523.69

PP (1ST DIFFERENCE AND INTERCEPT) OF GDP

Null Hypothesis: D(GDP) has a unit root
 Exogenous: Constant
 Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-4.737176	0.0004
Test critical values:		
1% level	-3.610453	
5% level	-2.938987	
10% level	-2.607932	
*MacKinnon (1996) one-sided p-values.		
Residual variance (no correction)		64835.98
HAC corrected variance (Bartlett kernel)		65020.54

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PP (1ST DIFFERENCE, TREND AND INTERCEPT) OF GDP

Null Hypothesis: D(GDP) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-4.447645	0.0055
Test critical values:		
1% level	-4.211868	
5% level	-3.529758	
10% level	-3.196411	

*MacKinnon (1996) one-sided p-values.

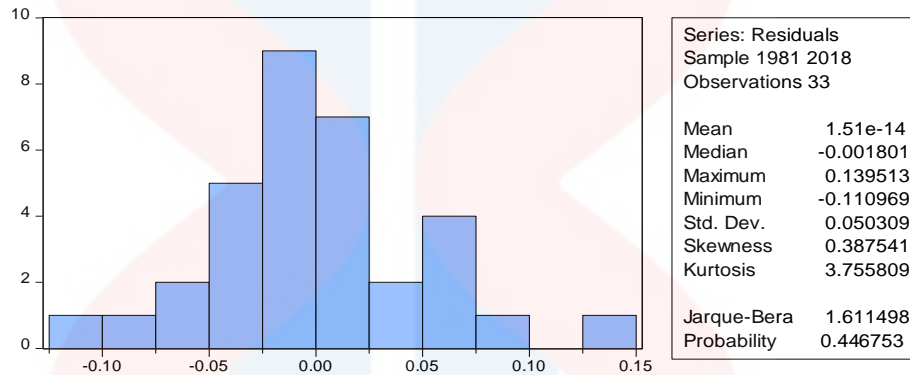
Residual variance (no correction)	64454.68
HAC corrected variance (Bartlett kernel)	59361.16

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APPEBDIX E

Diagnostic Test

A. Normality Test



B. Serial Correlation

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.551763	Prob. F(2,25)	0.5828
Obs*R-squared	1.395074	Prob. Chi-Square(2)	0.4978

C. Heteroskedasticity Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.909462	Prob. F(5,27)	0.4895
Obs*R-squared	4.756704	Prob. Chi-Square(5)	0.4463
Scaled explained SS	4.387577	Prob. Chi-Square(5)	0.4951

D. Model Specification Test

RAMSEY test

Ramsey RESET Test
 Equation: UNTITLED
 Specification: LNCO LNCO(-1) LNTOP LNEC LNGDPPC LNGDPPC2 C
 Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	0.585024	26	0.5636
F-statistic	0.342253	(1, 26)	0.5636

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	0.001052	1	0.001052
Restricted SSR	0.080991	27	0.003000
Unrestricted SSR	0.079939	26	0.003075

