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Date: 6th September 2017

UNIVERSITI TEKNOLOGI PETRONAS

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Date: 6th September 2017

FACTORS AFFECTING CO_2 EMISSIONS IN MALAYSIA: DO TECHNOLOGICAL INNOVATION, STRUCTURAL CHANGES, AND INTEREST RATE MATTER?

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WAJAHAT ALI

A Thesis

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UNIVERSITI TEKNOLOGI PETRONAS

BANDAR SERI ISKANDAR,

PERAK

SEPTEMBER 2017

DECLARATION OF THESIS

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I WAJAHAT ALI

hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTP or other institutions.

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Date: 6th September 2017

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DEDICATION

To My Parents, Siblings, My Lovely Wife, and My Little Angel, Aaleen Fatima, for their Endless Love, Prayers, and Support

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ABSTRACT

Global warming and climate change due to environmental pollution have been the center stage of discussion for the last two decades. To empirically investigate the problem of environmental pollution due to Carbon Dioxide (CO_2) emissions, the current study analyzed the relationship between the selected determinants of CO_2 emissions in Malaysia under the environmental Kuznets curve (EKC) hypothesis over the period 1971-2013. The study employed the cointegration techniques of autoregressive distributed lagged (ARDL) bound test and Johansen cointegration to detect the presence of long-run relationship while the short and long run estimates of the study were analyzed using the ARDL model. The results validated the presence of EKC hypothesis in two out of three models. The results also reveal that technological innovation and structural changes in the economy can improve the environmental quality. Furthermore, the study demonstrates that high rate of interest, trade openness, and increase in population leads to further environmental degradation. The results suggest that the course of energy consumption should be altered to renewables as energy efficiency and renewable energy resources can significantly affect the energy-related CO_2 emissions. The installations of less emitting environment-friendly technologies along with developed financial sector could improve the environmental quality and ensure the long-run economic growth. Likewise, a more services oriented economy could also help reduce the carbon emissions. Low interest rates can be helpful in stimulating and steering the investments in environmental protection and green technology. The results supported the Ramsay-Cass-Koopmans Model of low interest rate.

ABSTRAK

Pemanasan global dan perubahan cuaca disebabkan oleh pencemaran alam sekitar telah menjadi fokus perbincangan semenjak dua dekad yang lalu. Untuk menyiasat masalah pencemaran alam sekitar disebabkan oleh pelepasan karbon dioksida (CO_2), kajian semasa menganalisis hubungan diantara pelepasan penentu CO_2 yang terpilih di Malaysia di bawah hipotesis Lengkung Kuznets alam sekitar (EKC) dalam tempoh 1971-2013. Kajian ini menggunakan teknik kointegrasi iaitu ujian Autoregresif Lat *Teragih* (ARDL) dan kointegrasi Johansen untuk mengesan kehadiran hubungan jangka panjang manakala anggaran jangka pendek dan jangka panjang kajian dianalisis dengan menggunakan model ARDL. Keputusan telah mengesahkan kehadiran hipotesis EKC dalam dua model daripada tiga model. Keputusan juga menunjukkan bahawa inovasi teknologikal dan struktur perubahan teknologi dalam ekonomi boleh meningkatkan kualiti alam sekitar. Keputusan mencadangkan penggunaan tenaga patut diubah kepada tenaga boleh diperbaharui kerana kecekapan tenaga dan sumber tenaga boleh diperbaharui mampu mempengaruhi tenaga berkaitan pelepasan CO_2. Tambahan pula, kajian menunjukkan bahawa kadar faedah yang tinggi, keterbukaan perdagangan, dan pertambahan populasi menyumbang kepada kemerosotan alam sekitar. Pemasangan teknologi mesra alam sekitar yang kurang mengeluarkan bersama-sama dengan pertumbuhan sektor kewangan boleh meningkatkan kualiti alam sekitar dan memastikan pertumbuhan ekonomi jangka panjang. Begitu juga, ekonomi yang lebih berorientasikan perkhidmatan juga boleh membantu mengurangkan pelepasan karbon. Kadar faedah yang rendah boleh membantu dalam merangsang dan memacu pelaburan dalam perlindungan alam sekitar dan teknologi hijau. Keputusan menyokong Model Ramsay-Cass-Koopmans kadar faedah yang rendah.

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey-Fuller
AGW	Anthropogenic Global Warming
AIC	Akaike Information Criterion
APERC	Asia Pacific Energy Research Centre
API	Air Pollution Index
AR	Autoregressive
ARCH	Autoregressive Conditional Heteroscedasticity
ARDL	Autoregressive Distributed Lagged Model
ASEAN	Association of Southeast Asian Nations
BP	British Petroleum
CDIAC	Carbon Dioxide Information and Analysis Center
CO_2	Carbon Dioxide
CUSUM	Cumulative Sum of Recursive Residuals
CUSUMSQ	Cumulative Sum of Squares of Recursive Residuals
DF-GLS	Dickey Fuller Generalized Least Square
DICE	Dynamic Integrated Climate-Economy
DOSM	Department of Statistics Malaysia
DW	Durbin-Watson
EC	Energy Consumption
ECM	Error Correction Mechanism
ECT	Error Correction Term
EEVs	Energy Efficient Vehicles
EIA	Energy Information Administration
EKC	Environmental Kuznets Curve
EPU	Economic Planning Unit
ETP	Economic Transformation Programme
FD	Financial Development
FDI	Foreign Direct Investments
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GMM	Generalized Method of Moments
GTP	Government Transformation Programme

HQ	Hannan-Quinn Criterion
IAA	Innovative Accounting Approach
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
INDVA	Industry Value Added
IPCC	Intergovernmental Panel on Climate Change
JB	Jarque-Bera
KPSS	Kwiatkowski-Philips Schmidt Shin
LM	Lagrange multiplier
LR	Likelihood Ratio
M2	Broad Money
MENA	Middle East and North African
MNREM	Minnesota Renewable Energy Marketplace
MOF	Ministry of Finance
MP	Malaysia Plan
NAHRIM	National Hydraulic Research Institute of Malaysia
NEM	New Economic Model
NKRAs	National Key Result Areas
NOAA	National Oceanic and Atmospheric Administration
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
POP	Total Population
PP	Phillips-Perron
PPM	Parts per Million
R&D	Research and Development
RESET	Regression Error Specification Estimation Test
RIR	Real Interest Rate
SCC	Social Cost of Carbon
SCOPE	Scientific Committee on Problems of the Environment
SIC	Schwarz Information Criterion
SO_2	Sulphur Dioxide
SWM	Solid Waste Management
TI	Technological innovation
TPES	Total Primary Energy Supply
UECM	Unrestricted Equilibrium Correction Model

UNEP	United Nations Environment Programme
UNFCC	United Nations Framework on Climate Change
VECM	Vector Error Correction Model

LIST OF SYMBOLS

β	(Beta) Constant or Drift Element
$\beta_{1,2\ldots.k}$	Slope Coeffecients (Coefficients of Independent variables)
ε	Epsilon (Error Term)
φ	Phi (Long-run estimates)
μ	Error term for population
$<$	Less than
$>$	Greater than
∇	Difference Operator
∂	Parital Derivative
η	Eta (Parameter of the efficiency of environmental quality)
ψ	Psi (Parameter of the efficiency of environmental quality)
λ	Lembda (shadow prices of capital and stock of pollution)
κ	Number of Paremeters
$\sum$	Sigma (Showing the short-run estimates)
r_t	Marginal Productivity of manufacturing sector
ρ_t	Marginal Productivity of Services Sector
θ	Elasticity of marginal utility of Consumption
ω	Elasticity of marginal utility of stock of pollution

CHAPTER 1

INTRODUCTION

1.1 Introduction

The first chapter of the current thesis is organized into the following sections. Section 1.2 of the chapter discusses the background of the study. Section 1.3 represents the problem statement of the research. Section 1.4 depicts the research questions, and section 1.5 elaborates the research objectives in line with the research questions. Section 1.6 of the chapter discusses the significance of the study. Section 1.7 explains the motivation and scope of the study. Finally, section 1.8 depicts the overall thesis' organization.

1.2 Background

The Earth is a natural gift and only livable planet in the whole universe where human race is surviving easily than it can survive on any other planet. The earth's atmosphere and temperature are kept as such that human beings can survive here and can carry out their normal human activities. The Earth's atmosphere is composed of many gasses called the greenhouse gasses (GHG) which keep the world warm and livable. Present day human activities like more and more economic growth, industrial activities, exploitation of fossil fuels, extensive deforestation and emissions of greenhouse gasses in the atmosphere convert the balance between the percentage concentrations of these GHG into imbalance by emitting a large amount of Carbon dioxide (CO_2) gas. It is believed that when the concentration of these GHG increases in the atmosphere, it will give rise to the temperature of the earth's atmosphere and extreme changes will be observed in the ecological system of the world and the earth will almost become unlivable. These GHG emissions are the results of human activities and they have gained acceleration after the industrial revolution.

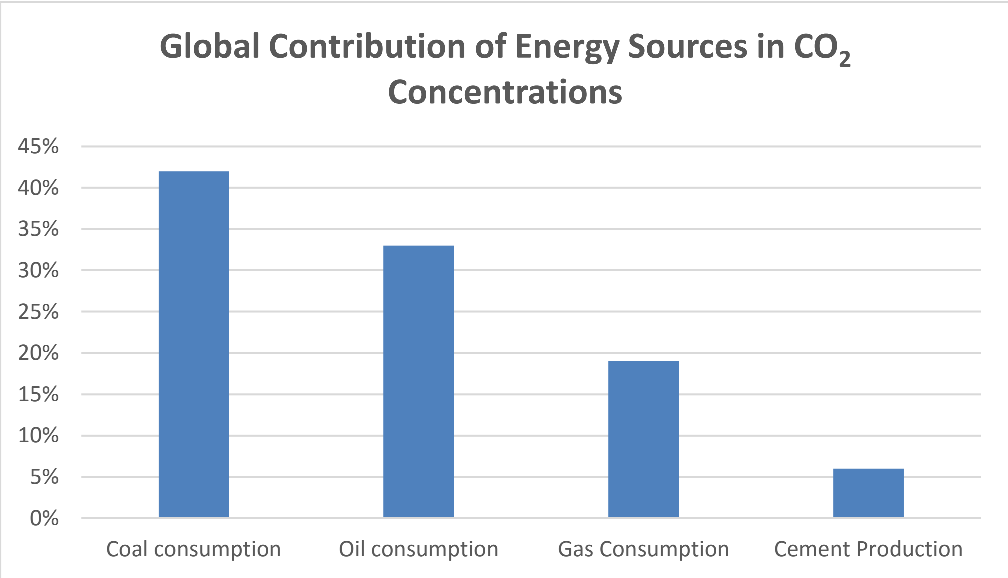
The idea that human activities could lead to changes in the climate has been long suspected. The debate that how deforestation might change the pattern of rain, less or more, was the hot issue in the early 19th century. But there occurred great changes in the climate and especially the discovery of ice ages confirmed that climate changes occurred over all the globe and it gave rise to a debate that what is the cause of these changes in the climate system. Some questions were raised about it, that it might be the cause of changes in the heat from the Sun or may be due to the eruption of volcanoes. Similarly, some people believed wind patterns and changes in the ocean currents might be because of raising and lowering of the mountain ranges. Some people questioned that it might also be the cause of the changes in the air composition.

The Earth's atmosphere is having a huge amount of carbon dioxide and the reforms indicate that the concentration of CO_2 has varied over different periods of time from about 7,000 Parts per million (ppm) to 180 ppm between the Cambrian and Quaternary Glaciation period[1]. It is argued that the increase in the carbon's concentrations in the atmosphere of the Earth is the basic reason for the recent phenomenon of global warming. An annual mean rise in the concentration of CO_2 (from 280 ppm to 400 ppm in 2015) has been observed since the Industrial Revolution (NOAA, 2016). The main culprits of this increase in the CO_2 concentrations are the burning of fossil fuels and deforestation by mankind. Carbon dioxide (CO_2) gas has currently crossed 400 parts per million (0.04%) of the Earth's atmosphere (404 ppm, April 2016) (NOAA, 2016b). It is believed that about 2,000 gigatonnes of carbon dioxide have been emitted by the humans since 1750. Out of the total 91% of carbon emissions in the atmosphere 42% are released from coal consumption, 33% are from the consumption of oil, gas is responsible for 19% of emissions and 6% of these emissions are due to the production

[1] https://books.google.com.my/books?id=hFkpCgAAQBAJ&pg=PT84&lpg=PT84&dq==bl&ots=qICt3dXt0n&sig=njeL0iycQlBObXmXnFnApytwgSk&hl=en&sa=X&redir_esc=y#v=onepage&q=7%2C000%20Parts%20per%20million%20(ppm)%20to%20180%20ppm%20between%20the%20Cambrian%20and%20Quaternary%20Glaciation%20period&f=false

of cement as shown in Figure 1.1. The contribution of the land use to the total concentrations of CO_2 emissions is about 9% (CDIAC, 2015).

Figure 1.1: Global Contribution of Energy Sources in CO_2 Concentrations



***Source**: Authors Creativity Based on CDIAC Data (2015)*

The deterioration of the environment or disintegration of the earth; the eradication of the wildlife and the destruction of the environment is called the environmental degradation. The environmental degradation is characterized by any unwanted and malicious exacerbation or change in nature. The depletion or extinction of the natural resources, including different species, water, land, and air pollution results in environmental degradation. Similarly, the diminishing of the Earth's ability to fulfill the natural and societal needs and objectives of the people is called environmental degradation[2]. The human activities, especially agriculture and clearing of land, fossil fuel burning are the main problems of the present world as they are increasing the GHG concentrations, and this enhances the greenhouse effect which leads to the warming of the Earth (Department of Environment, Australian Government, 2012).

Carbon dioxide plays a key part in maintaining the temperature and life on earth and is an important part of the carbon cycle, exchanging the carbon between oceans,

[2] https://www.unisdr.org/we/inform/terminology

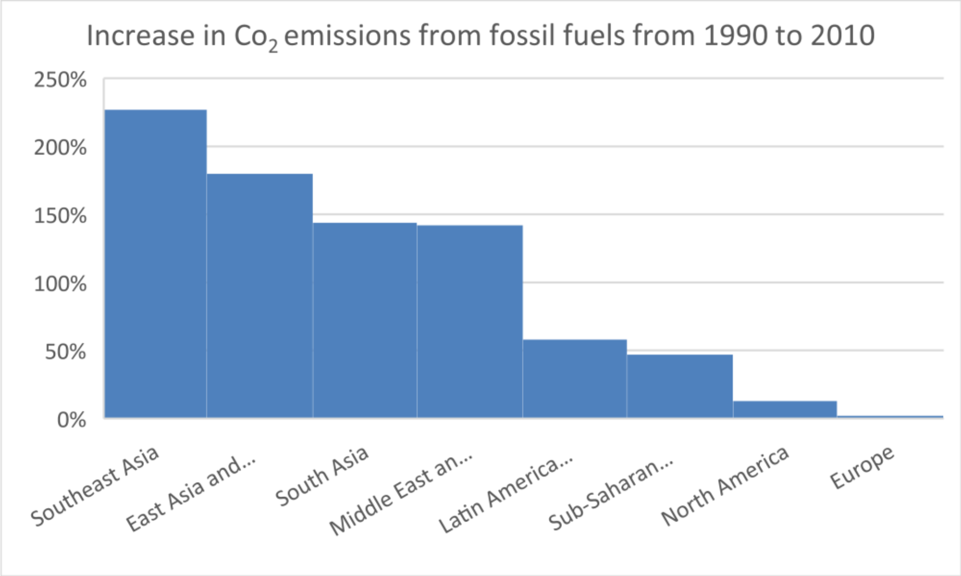
biosphere, rocks and soil. Carbon dioxide is used as an energy source by plants and other photoautotrophs to construct their body parts. The present-day Earth is biosphere due to the atmospheric CO_2, but if these concentration increases very much then they are creating a greater problem like global warming and climate change which are not desirable to the life on this planet. The threat of global warming is increasing, and the changes in the climate of the earth has attracted the attention of the researchers and environmentalists to examine the connection between economic growth, energy consumption, and environmental pollution. The GHG which are considered the leading cause of global warming have different consequences regarding the countries social and natural characteristics. It is argued that since 1750 pollutants from manufacturing activities, wastes, and effluents has added more than 1850 billion tons of CO_2 emissions in the atmosphere (Opschoor, 2010; Senge, Smith et al., 2009). The burning of fossil fuels over a range of more than 200 years has led to the atmospheric pollution, which is one of the basic reasons of global warming and climate change (D. D. Green & McCann, 2011). So far, there has been an increase of 0.8^0 C in the world's temperature which have earth shattering impact on the global climate (Dunphy, 2012). The Scientific Committee on Problems of the Environment (SCOPE) in 1986 stated that if the CO_2 continues to rise by the same rate, it would reach almost double of its pre-industrial values in the 21st century. Stern *et al*. (2006) reported that the concentration of GHG in the atmosphere will become nearly double from its pre-industrial level by 2035 if no action is taken to control the emissions. This finding indicates that if this is the pace of GHG emissions the average world temperature may increase by 2^0C in the short-run. There is a danger that the temperature may rise by more than 5^0C in the longer term. Stern (2006) emphasized that all the countries will be affected by this temperature change, the populous and poor would be hit hard and early regardless of their less contribution to polluting the environment.

It is the use of coal, petroleum and gas, which triggers the industrialization which in turn make it possible for the humankind to live a high standard life. However, the use of these resources in abundant amount create some negative externalities which harm the environment because the current pattern of production and consumption of fossil fuels is problematic. The businesses and firms ignore these externalities because they are not affected directly by these externalities (Gale, Brown, & Saltiel, 2013). The continuous use of these fossil fuels to a high amount emits different GHG and these GHG create the greenhouse effect which affects the temperature of the earth's atmosphere, and it is leading to global warming. The increasing threat of global warming due to the increase in greenhouse emissions is noted in the last two and half decades. The primary cause of which is the carbon dioxide that accounts for 58.8% of greenhouse gasses in the world (Zhenling, 2013). The CO_2 emissions have increased three times between 1960 and 2008 and there occur a change in the main actors. The percentage contribution to the global carbon dioxide emissions by countries have increased and changed i.e. the contribution of China, India and the rest of the world were 9%, 1% and 10% respectively in 1960 and it changed to 28% by China, 6% by India. USA, EU-28, Russian Federation, and Japan are responsible for 16%, 10%, 6%, and 4% fossil fuels based CO_2 emissions in 2011, while the rest of the world is contributing 30%. This increase in the emissions is due to the energy consumption where electricity generation is one of the main culprits.

Southeast Asia, having the consistent and high rainfall, is categorized with abundant tropical rainforests and monsoon climates. This region has different topological scales as a vast area of the region is oceanic continents. The weather and climate of the region are strongly affected by the complex combination of land, sea, and the mountains. The Fifth Assessment Report of IPCC has focused on the climate situation in South and Southeast Asia. In the current climate scenarios, the increasing trends in temperature and warming of the climate is like the region's past century's temperature (IPCC, 2014). According to the Asian Development Bank (ADB) report, South Asia's most precious resource (water) is very vulnerable to climate change as since 1950 because of rapid increase in urbanization and population, the per capita water availability has fallen by 70% (ADB, 2012-2013). According to Bloomberg report, Southeast Asia has observed an increase of 227% in CO_2 emissions which is more than any part of the world between 1990 and 2010. Since South Asian economies are growing very rapidly, thus are emitting a huge amount of CO_2 emissions in the atmosphere. The fires from peatland and forest in 2015 have resulted in gigantic amount of CO_2 emissions which are the largest since 1997. The 2015 fires resulted in a release of 884 million tons of CO_2

emissions in which 97% of the CO_2 was from fires in Indonesia. It is evidenced that the due to landscape fires 11.3 million tons of regional CO_2 emissions were released in September and October 2015, which are greater than 8.9 million tons of CO_2 emitted by European Union on daily basis (Center for International Forestry Research, 2016)[3].

Figure 1.2: Increase in CO_2 Emissions of South East Asia and Rest of the World



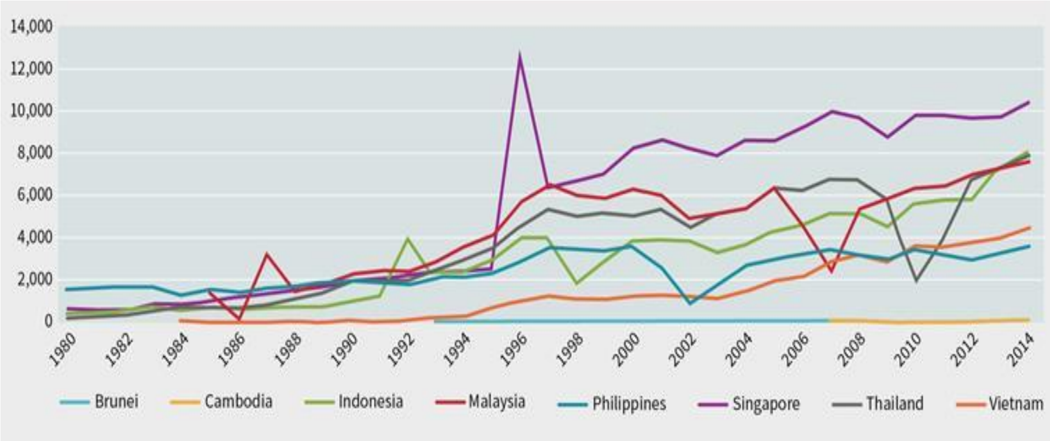
***Source**: Asian Development Bank and Bloomberg*

It is argued that Southeast Asia is an attractive place in terms of innovative technology and there is a clear evidence of the R&D support from the governments in the area as they realized that the secret of smooth economic growth and self-sufficiency in technology. There is a clear social and political strive in the economies to move towards economies which are knowledge and services based rather than manufacturing based economies. There is a shift in the process of manufacturing, and the present-day manufacturing is more automated, thus, it requires less labor force to assemble a widget, therefore, the importance of technological innovation is evident[4].

[3] http://www.cifor.org/press-releases/carbon-emissions-2015-fires-southeast-asia-greatest-since-1997-new-study/

[4] http://www.iam-media.com/magazine/issue/81/Features/Southeast-Asia-the-innovation-outsider

Figure 1.3: Total Patent Application (direct and PCT) in Southeast Asian Countries 1980-2014



Source: *World Intellectual Property Organization NB: Myanmar and Laos and not included due to incomplete/unavailable data.*

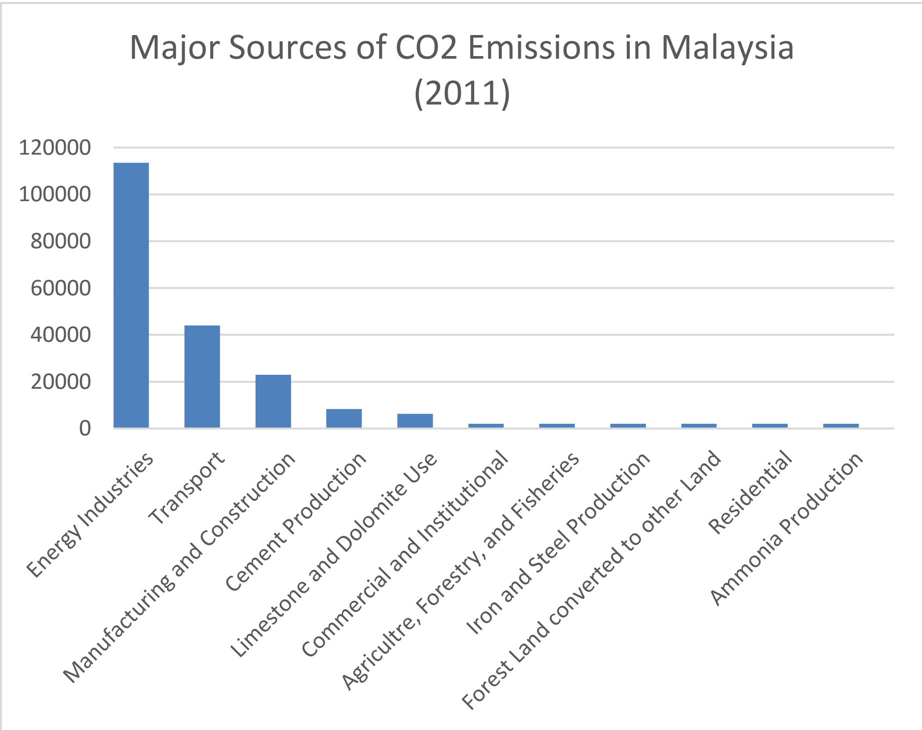
Among the ASEAN countries, Malaysia is the second largest emitter of the per capita greenhouse gasses (Salahudin *et al*., 2013). The share of Malaysia in the total global GHG emissions is as small as only 0.3% (Olivier *et al*., 2013), but the real concern is the ever increasing trend of GHG emissions. Many of the developed economies of the world have successfully reduced the environmental pollution by controlling the GHG emissions, while Malaysia is still having an increasing trend in emissions level and have already crossed several developed economies in emitting the GHG emissions (Salahudin *et al*., 2013). Malaysia has two distinct parts, Peninsular Malaysia and the East Malaysia. Thailand, Indonesia, and Singapore are on the borders of Peninsular Malaysia while the Borneo area of East Malaysia shares the border line with Brunei and Indonesia. Being categorized as equatorial, the climate of Malaysia is humid and tropical. The complex interactions of land-sea and mountain structures influence the climate of the country. The average annual rainfall in the country is 2500 mm (Hock, 2007) and the average temperature ranges from 20^0C to 30^0C, around 27^0C mostly (World Weather and Climate Information, 2016). Malaysia seems to be exposed to the climate change as the rainfall can increase, the sea level can rise, floods and droughts are expected due to its location on the equator line and is prone to the climate change. Both the East and West Malaysia are prone to the tropical storms in the South

China Sea and it has contributed a lot in the extreme events of gusting winds and rainfall.

Malaysia is among the fast-developing countries in the ASEAN region. The country is environmentally one of the rich having a lot of natural resources, renewable and non-renewable energy resources, and high biodiversity. It is a big supplier of tin (32%), palm oil (37%), hardwoods (39%) and natural rubber (41%) in the world. Malaysia, a developing country with a population of 30 million, accounting for 0.42% of world population and emitting 0.64% of total global carbon emissions (Index Mundi, Malaysia Demographic Profile 2014). The carbon dioxide emissions are responsible for about 95% of the total GHG emissions by Malaysia, therefore reducing the CO_2 emissions in Malaysia can be of grave importance to influence the global warming and the greenhouse effect (Index Mundi, 2014). This rapid increase in the country's carbon emissions is due to the vigorous extension of the automotive and industrial sectors of the country, the over usage of total primary energy supply (TPES) regarding fossil fuels, conversion of grasslands and forests into agricultural lands and buildings, and the unsustainable waste management. The emissions growth rate of Malaysia as a developing country is one of the fastest in the world with a growth rate of around 7%. The country is ranked very low in the environmental performance of the earth policy institute and climate change performance index in 2012. Malaysia has been ranked as the 27th most polluted country in the report of the earth policy institute emitting a total of 54 million tons and the average growth rate of last five years was 13 percent. Similarly, Malaysia has been ranked 49th out of a total of 61 most polluted countries of the world by the climate change performance index ranked in 2012. Malaysia is a member of many international agreements meant to reduce the greenhouse gas emissions, including Montreal protocol of 1987, Kyoto Protocol of 1992, Bali Road Map 2007, Copenhagen accord of 2009, and Cancun agreements of 2010 among others (Mason-Case, 2011). The current environmental pollution situation in Malaysia indicates that these policies and acts are somehow unable to control the environmental pollution in the sense of CO_2 emissions and deforestation and there is a need to further investigate the problem.

Over the period of independence, the economic growth of Malaysia has remained in the higher quartile and the country is positioned at 12th place overall the world in 2014 and is ahead of some of the developed economies of the world including Japan (21), United Kingdom (16), New Zealand (20), and South Korea (35)[5]. This rapid growth of the country is due to the vast utilization of natural resources including coal, oil, gas and others which are some of the main causes of CO_2 emissions in the atmosphere. A total of 208,253 Gg tons of CO_2 was emitted in 2011 with the highest of 113,567 Gg CO_2 (55%) from the energy industries, 44,007 Gg CO_2 (21%) from transport sector, and 23,004 Gg CO_2 (11%) from manufacturing and construction activities.

Figure 1.4: Major Sources of CO_2 Emissions in Malaysia (2011)



The government of Malaysia under its 2020 vision is trying to reduce the CO_2 emission by 40% of the 1990 level and has implemented some regulatory acts and laws to reduce the CO_2 emissions from different economic and industrial activities. The

[5] https://www.triplehelixassociation.org/helice/volume-4-2015/helice-issue-12/innovation-in-malaysia-the-next-step

government of Malaysia has formulated some environmental protection policies and acts as shown in the Table 1.1.

Table 1.1: Environmental Protection Policies in Malaysia

Regulation	**Year**	**Purpose**
The Wild Life Protection	1972	To protect the wild species
Environmental Quality Act	1974	To protect environmental pollution
National Petroleum Policy	1975	The efficient utilization of resources
National Energy policy	1979	To make the supplies secure, efficient and environmentally sustainable
National Depletion policy	1980	To protect the exploitation of national oil reserves
Four-Fuel Diversification Policy	1981	To introduce the other sources like Coal, Gas, and Hydro to reduce the dependency on Oil
National Forestry Act	1984	To protect the illegal logging and deforestation
Natural Resource and Environment ordinance	1979	To ensure efficient use of natural resources and environment
National Policy on Biological Diversity	1998	To conserve the Ecosystem
Five Fuel Diversity	2001	To include renewable energy resource in the energy mix
National Policy on Environment	2002	To protect further environmental degradation
Kyoto Protocol Ratification	2002	To reduce the CO_2 emissions to the 1990s level
National Strategic Plan for Solid Waste Management	2005	To assess the problem related to the waste disposal and to convert wastes to energy by recycling

The government further implemented the Biofuel Policy in 2006 to reduce the dependency on the scarce and polluting energy resources and to use the sustainable, environment-friendly, and possible alternative energy resources to control the environmental pollution. National Energy Policy (2008) was implemented to minimize the negative externalities of energy production, distribution, utilization, conversion, and consumption. The government also implemented the 'National Green Technology Policy' in 2009 to encourage investments in the green technology to improve the environmental quality in the country by developing and implementing the equipment, products, and system that can be used for conserving the natural resources and environment, by reducing the harmful effects of the human deeds (Ministry of Energy

Green Technology and Water, 2010). The ‘National Policy on Climate Change (2009) was adopted to mainstream the changes in the climate via prudent resource management and improved environmental conservation to provide climate-resilient development to fulfill the national aspirations for sustainability. The policy aims to reduce deleterious impact of the changes in the climate by establishing the implementation capacity by improving the quality of institutions (MNREM, 2009).

The ‘New Economic Model (NEM)’ was introduced to get higher income status and to benefit all communities in the circle of sustainability without compromising the future generations. The government focused on the ‘Government Transformation Program (GTP)’ to make sure that the national key result areas (NKRAs) are more public-sector dominance, and ‘Economic Transformation Program (ETP)’ to make the country high-income economy which is both sustainable and inclusive. The NEM also encompass the 10^{th} Malaysian Plan, which is designed to take forward the aspirations of the GTP and NEM, to make the economy high income, sustainable and inclusive. The 10^{th} MP focused on the major structural transformations to match the requirements of the high-income economy. The government further introduced the “Renewable Energy Policy and Action Plan” in 2010 to increase the role of renewables in the electricity generation by facilitating the RE industries via ensuring the reasonable production costs, and enhancing the public awareness about the important role of renewable energy to preserve the environment for future generations. Similarly, the government implemented the Second National Physical Plan in 2010 to support the development planning by giving dimensions to national socio-economic plan and to ensure the sustainable development by providing the national, regional and local planning. Furthermore, the government introduces the ‘Low Carbon Cities Framework’ in 2011 to promote and encourage the low carbon cities and townships, to guide cities towards a greener solution, and to assist the stakeholders to devise the plan for low carbon development.

Moreover, the government implemented the National Agro-food Policy in 2011 to increase the food security and to improve the competition and productivity on the national and international level by introducing the involvement of technology. The

National Water Resources Policy was introduced in 2012 to secure the adequate availability of pure water to all and to make the water resources sustainable. Last but not the least the government implemented the ‘National Automotive Policy’ in 2014 to develop the capability and competitive automotive industry, present Malaysia as the hub for energy efficient vehicles (EEVs), increase the exports of vehicles and spare parts, and enhance the ecosystem of the manufacturing and aftermarket sectors of the domestic automotive industries. Malaysia under the Cancun agreement and Bali declaration has announced at the Copenhagen convention in 2009 that the country will reduce the carbon emissions by 40 percent intensity of GDP to levels of 2005 by 2020 voluntarily as a part of their 2020 vision (Theseria, 2010).

Malaysia is facing with some hurdles and gaps in the current set up handling the GHG emissions at different economic and other sector in terms of technological advancement and capacity building. The country is confronted with problems in adaptation to the climate change impacts, while making sure the protection of the development gains from economic activities. In general, the climate change mitigation action is confronted with some continuous hurdles in the fields of institutional arrangements, financial support, and regulatory actions. A continuous and substantial financial support, sustained development of the technical capacity, and a suitable worldwide alliance is needed to bridge these gaps.

1.3 Problem Statement

The exploitation of natural resources and fossil fuels to propel more economic growth is the general approach among the countries of the world. The burning of these fossil fuels and the use of other resources in the pursuit of economic growth keep the heat on, and the Earth is becoming warmer and warmer, but the governments of the world are acting at a snail’s pace to stop further spiking up of the mercury. Environmental degradation and CO_2 emissions due to economic activities are of great concern to the scientists, environmentalists and policymakers these days. Economic growth and consumption of energy are necessary for every country, but this growth and energy consumption increases the concentration of GHG gases especially CO_2 in the atmosphere. It is argued that the world is approaching a climate Armageddon due to tiny political will and too much politicking. This global warming and climate change due to continuous emissions of CO_2 will make the Earth almost unlivable, and there may be no planet we can call home after 2100 (Masilamany, 2013). "Turn Down the Heat: Why a 4^0C Warmer World Must be Avoided" a World Bank report in 2012 explains that the world will reach an increase of 4^0C on average by the end of the century. This much rise is almost double what is considered safe for the Earth by scientists to be livable and to avoid the most devastating climate events. In an analysis, the Potsdam Institute for Climate Impact Research (PIK) stated that there will be a cataract of earth-shattering changes. These changes in the climate in turn will cause, the decline in global food stocks, rise the sea level and the extreme heatwaves if there is no immediate action taken against the climate change by the world community. The mean temperature rises of 0.3 to 0.6% has been globally observed over the past 100 years (Hansen & Lebedeff, 1987, 1988; IPCC, 2001; P.D. Jones, 1988). This rise in the global temperature got the acceleration from the mid-1970s and an increase of 1.35^0C is observed since 1979 until 2016 (Feb) (Arguimbau, 2016). The CO_2 concentrations have increased at an average of approximately 2 ppm/year at an accelerating rate, but in 2015 the average rate has increased up to 3.05 ppm per year (NOAA, 2016b).

Malaysia as a fast-developing country emit CO_2 like other countries of the world due to economic growth and enormous energy consumption. Malaysia is dependent on the non-renewables, including oil, natural gas, and coal to meet its energy demand. The consumption of these resources emits a huge amount of GHG especially CO_2 emissions in the atmosphere in the process of production and consumption, and the waste products in the rivers and sea. Among the other sources, one of the prime reasons of environmental pollution in Malaysia is the economic growth, which requires the change in the land use to convert the forests into agricultural land and rapid construction of buildings to get more development, thus, causing an increase in the deforestation. The water pollution is also one of the fundamental problems of Malaysia and the Environmental Quality Act of 1974 and other environmental laws are not able to control the nation's water contamination as 40% of the water is polluted. The cities of Malaysia produce annual 1.5 million tons of solid waste. To monitor the air pollution, the government introduced Clean-air legislation in 1978 to limit the emissions from industries and automobiles. However, both the sources are emitting a significant amount of CO_2. The industrial carbon dioxide emission of Malaysia was ranked among top 50 nations having a 3.74 metric ton per capita annually and a total of 70.5 million tonnes per year. The National Forestry Act was introduced in 1984 to control the fast deforestation, but the five states of Malaysia including Kelantan, Pahang, Johor, Terengganu and Perak lost 10% of the forest area between 2001 and 2012 (Global Forest Watch, 2013). The deforestation rate in Malaysia was the highest in the world with a rate of 14.4% between 2000 and 2012 (Butler, 2013). The per capita CO_2 emissions in Malaysia increased from 1.583 to 3.108 metric tons (1974-1990) and it further goes up to metric tons 7.9 in 2011 (WDI, 2016). The total carbon emission in Malaysia has increased from 8.83 metric tons in 1970 to 258.30 metric tons in 2013 (British Petroleum, 2014). The country was ranked 28th in the worldwide ranking on the basis of the CO_2 emissions from fossil fuels and it moved up to 26th position in 2012 (Index Mundi., 2014; Najib (Malaysian digest.com, 2015)). The Air pollution index increases up to 500 in Port Klang in 2005 where a state of emergency was declared, all the schools and universities were closed (API, Department of Environment, Malaysia, 2010).

If the economic growth in the country is not on the environment-friendly and sustainable basis, and the CO_2 emissions are not controlled and it increases with the same pace, it will lead to climate change. An increase of above 2^0C (3^0- 4^0C), will increase the annual rainfall in Malaysia by 15%, water demand for domestic and irrigation purposes by 15%, the evapotranspiration by about 20-25%, the sea level will rise by 40-100 cm. These changes, in turn, will cause more land to flood in low coastal areas by 2.5km further inland, the lowland production of crops, including rice, oil palm, and rubber will decrease by about 15-20%; and will destroy the estuarine and mangrove habitats (Razali & Mohd, 2010). Rice which is the main daily consumption ingredient in Malaysia will face a decrease of 12 and 31% by 2030 due to the rise in temperature and changes in the patterns of rain during the main season and off growing seasons respectively (Vaghefi *et al*., 2015). The emissions trend is increasing at 6% per annum as it will increase from 54Mt in 1990 to 235Mt in 2030 (Asia Pacific Energy Research Centre (APERC), 2013). The increase in the per decade mean temperature of the Earth's surface is observed to be 0.14°C- 0.25°C. The minimum increase in per decade surface temperature is noted to be 0.17°C-0.22°C, while the observed rise in the per decade maximum temperature of the surface is 0.20°C-0.32°C (INDC report to UNFCC, 2015). On the other hand, the mean sea level rise in a range of 2.3 to 7.0 mm/year is observed around the Malaysia coasts (NAHRIM, 2010). A report on Climate and Health Control's profile claimed that there will be an increase of 4^0C in the annual mean temperature between 1990 and 2100 if the emissions are increasing at the current increasing rate. The report claimed that if the emissions decreased rapidly, the temperature rise will be limited to about 1.1°C. Similarly, the projected number of people affected by the flooding will be 234,500 due to rise in the sea level between 2070 and 2100 (Climate and Health Control Profile, Malaysia, 2015). The government of Malaysia faces an average direct annual loss of RM915 million from the floods in the country (MNREM, 2015). The total cost of climate change in Malaysia is projected to be RM40 trillion (US$10 trillion) in 2095 as per the researchers of Universiti Teknologi Malaysia and University of Malaya (Clean Malaysia, 2016).

Since economic growth is the predominant objective of each economy around the globe, and the achievement of higher economic growth requires the vast utilization of energy resources while performing different economic activities. It is claimed that environmental pollution because of economic activities is a barrier to achieve higher and sustainable economic growth, thus, to achieve the sustainable and higher economic growth, the problem of environmental pollution (increase in the CO_2 emissions) must be handled. Based on the description and previous literature on the consequences of the environmental pollution, the current study states that economic growth in Malaysia is polluting the environment by emitting huge amount of carbon dioxide in the atmosphere. Thus, economic growth in Malaysia is not sustainable in the long-run as it is at the cost of environmental quality. There are some macroeconomic determinants which emit carbon dioxide in the environment while some other activities can reduce these emissions in the process of achieving higher economic growth. Thus, the current study focused on the problem of environmental pollution due to continuous emissions of carbon dioxide while keeping the economic growth of the country in the high quartile. There are several studies conducted in this area, but the relationship between the variables of the studies are controversial for different countries in different contexts.

Thus, the current study is an effort to solve this problem of environmental pollution due to higher economic activities which emit carbon dioxide emissions in the atmosphere.

The current study investigates the impact of some of the macroeconomic determinants such as economic growth, energy consumption, financial development, and trade openness on the carbon dioxide emissions in the long-run in Malaysia over a period 1971-2013. The previous studies conducted in this area faced the omitted variables biases and some studies failed to give clear answers about the magnitude and directions of causalities due to the lack of appropriate econometric techniques. In the case of Malaysia as fast developing country, science and technology can play an important role in competitiveness bid for Malaysia. Unfortunately, there are some weaknesses in the innovation system and scientific structure of Malaysia and the country is ranked 33rd out of 143 countries in the Global Innovation Index (GII) 2014 (MASTIC, 2015)[6]. The energy supply structure as well as the problem of environmental emissions can be handled via the adoption of different advanced technologies. Since the Malaysian technological readiness is on low side and the main uncertainty is the development of the future technologies in the field of electricity generation, which will be decided based on the cost of the sources of energy (World Economic Forum, 2016)[7]. Therefore, it is necessary to focus on the improvement of technological innovation to cope with the problem of environmental pollution. Since, the impact of patent application on the environmental quality has been ignored in the previous literature. Thus, the current study further emphasized on the role of technological innovation (patent applications) under the endogenous growth theory for the first time in the income pollution relationship to investigate their impact on the environmental quality (CO_2 emissions) under the Environmental Kuznets Curve (EKC) hypothesis.

Similarly, the study emphasized on the role of real interest rate in the income pollution relationship under the EKC framework to investigate either the interest rate in the country is performing under the Ramsey-Cass-Koopmans model or the

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[6] MASTIC (Malaysian Science and Technology Information Centre), http://mastic.mosti.gov.my/en/web/guest/gii

[7] https://www.weforum.org/agenda/2015/04/which-asean-country-is-the-most-competitive/

Rybczynksi theorem. Furthermore, the study, for the first time in Malaysia, under the structural change hypothesis and Lewis' Structural changes theory, focused on the impact of structural change in the economy (industry value added % of GDP) on the CO_2 emissions in the EKC framework. This research is an effort to investigate which macroeconomic determinants are polluting the environment and which other determinants can improve the environmental quality by decreasing CO_2 emissions while achieving higher economic growth. The study under investigation aims to find out if there is any appropriate policy tool and technique which can be used to decrease the CO_2 emission in Malaysia in the process of economic growth. This research will be beneficial to the policy makers, government regulatory bodies, industrialists, manufacturers, public, researchers and students working in the same field.

1.4 Objectives of the Study

Based on the discussions in the literature, problem statement of this research, and the research gap found, the current study come up with some objectives to be determined during the study. The main objective of the current study is to investigate the long-run and causal relationship between carbon dioxide emissions and its different determinants in Malaysia. The main determinants of carbon emissions are energy consumption, economic growth, trade openness, structural changes in the economy, technological innovation in the country, interest rate changes, financial development, foreign direct investments, and total population. To solve this problem of environmental pollution due to carbon dioxide emissions in Malaysia, the current study come up with the following objectives.

1. To investigate the impact of technological innovation on the environmental pollution (CO_2)
2. To explore the impact of structural changes in the economy on the environment in Malaysia
3. To determine the role of interest rate in the income-pollution relationship in Malaysia

1.5 Research Questions

The contemporary study focuses on the long-run and causal association between carbon dioxide emissions and its determinants in Malaysia including economic growth, a different form of energy consumption, structural changes, technological innovation, interest rates, and some other determinants like trade openness, financial development, foreign direct investments, and population. The main question of the study is: what is the impact of these determinants on the environmental quality in Malaysia? Above all, the current study seeks to answer the following research questions which are in line with the objectives of the study.

1. How technological innovation in Malaysia can improve the environmental quality?
2. How structural changes in the economy can affect the environmental quality in Malaysia?
3. How can fluctuations in the real interest rate affect the environmental quality in Malaysia?

1.6 Significance of the Study

Based on the above discussion, it is evident that the relationship between carbon emissions and some of its determinants has not been explored extensively, especially in the case of Malaysia. Previous studies in the Malaysian context have examined the relationship between energy use, economic growth, and carbon emissions (Begum *et al.*, 2015; Heidari *et al.*, 2015; Saboori *et al.*, 2012; Saboori & Sulaiman, 2013; Salahuddin & Gow, 2014). Other researchers included financial development and international trade in the equation (Azam *et al.*, 2015; Islam *et al.*, 2013; Mugableh, 2013; Shahbaz *et al.*, 2013; Tang & Tan, 2014) and some other researchers emphasized on the role of urbanization and transportation (Al-Mulali & Ozturk, 2015; Azam *et al.*, 2015; Chandran & Tang, 2013; Hossain, 2011), while others focused on the role of population and FDI (Azam, Qayyum, Zaman, Ahmad, *et al.*, 2015; Begum *et al.*, 2015; Lau, Choong, & Eng, 2014). The current study extended the previous studies by investigating the association between carbon emissions and technological innovation in the presence of energy use, economic growth, and openness to trade. The role of technological innovation in environmental perspective has not been investigated previously and especially in the Malaysian context. Previous work on the role of technological innovation has emphasized on the role of R&D expenditure while the current study focused a new proxy in terms of patent applications to measure the technological innovation in Malaysia. Some of the previous researchers focused on the role of patent applications, but its relationship with environmental quality is very rare (Chu, 2014; D. Popp, 2005; Sohag *et* al., 2015). This study is important because it adds to the literature on the income-pollution by incorporating the role of patent applications. Similarly, this work could be helpful to policy makers and government bodies because it provides them with a clear picture about the role of technological innovation and they could implement the environment-friendly advanced technology to reduce the environmental pollution.

The current study is important because it extended the previous work and included the structural changes in the economy in the income-pollution equation to investigate its impact on environmental quality. The study focused on the role of industrial value added as a proxy to measure the role of shifts in the economy from the basic agriculture to the industrial sector and further to a services sector economy on the environment. Therefore, this study could be helpful to government bodies to focus more on the services economy to promote the economic growth and reduce environmental pollution. This research is also important because it emphasized the role of interest rate in the income-pollution equation. Previous studies focused on the role of interest rate as a discount rate to discount the future costs of climate change while the current study emphasized the role of real interest rate in altering the income-pollution relationship in Malaysia for the first time. Therefore, this study is important both on the basis of literature as it will add a new strand to the existing literature on the rate of interest and this could also be helpful to policymakers to understand the role of the interest rate in fluctuating the income-pollution relationship.

1.7 Scope of the Study

This research work is related to the global problem of environmental degradation due to the carbon emissions because of different economic activities. This study is confined to the determinants of carbon emissions in Malaysia over a period 1971-2013 to find out the possible solutions to the problem. The study utilized the world development indicators (WDI), Department of Statistics Malaysia (DOSM), British Petroleum (BP), Bursa Malaysia (Index Mundi), Carbon Dioxide Information Analysis Center (CDIAC), and Global Financial Development Database (GFDD) for data collection.

1.8 Organization of the Study

The current thesis is divided into five chapters. The first chapter comprised of the background, problem statement, objectives, research questions, and significance of the study. The second chapter is related to the theories, previous literature, and empirical findings of the previous researchers on the determinants of carbon emissions, including energy use, economic growth, development of financial sector, openness of trade, technological innovations, structural changes, and interest rate. This is followed by chapter three which discusses the conceptual framework of the research, research design, measurements of variables, and research methods to analyze the data. Chapter four of the study is about the results and discussions of the findings. The last and fifth chapter of the study provides the summary of the study, implications of the results, the limitations of the study, and the recommendations to the future researchers.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of previous studies on the topic under the study. The study covers the available literature on the relationship between economic growth and carbon dioxide emission in different contexts, including country specific case studies and panel studies, different methodologies adopted in the previous studies. Section 2.2 of this chapter focused on the reason why we have focused on carbon dioxide emissions. Section 2.3 discusses the reasons and the theoretical support for the inclusions of different variables in the income-pollution equation. The empirical literature on the variables of interest is given in Section 2.4 of the chapter. Section 2.5 discusses the empirical literature related to Malaysia. Summary of the chapter is presented in section 2.6 of this thesis.

2.2 Why Carbon Dioxide Emissions?

Environmental pollution due to greenhouse gasses (GHG) emissions, particularly the CO_2 is of grave concern to policy makers and environmentalists. The concentration of GHG gasses is increasing by the process of industrial production, and it will lead to climate change. After the industrial revolution, humanity appeared as a dangerous power of nature during the last few decades. The modern civilization has caused the economies of scale to be destructive by the adoption of new technological, economic and political choices driven by increasing use of fossil fuels. The consumption of different resources is more than this planet can absorb and the rate of population growth is alarming as it will reach up to 8 billion by 2030 so there will occur an enormous increase in the demand for fossil fuel energy use, water, food and land use which will lead to more GHG emissions through the more use of transportation, industry, and deforestation. The human beings are changing the whole biological, physical and chemical system of the planet, by consuming more and more fossil fuels and also by deforestation for heating and home fire purposes, which leads to global heating and pollution. The paleoclimate evidence and current change in climate recommend that to make the earth, and this planet livable the ppm of CO_2 must reduce from 385 ppm to 350 ppm at most (Hansen *et al*., 2008). To prevent the world from a cascade of disasters, there is a dire need to decrease the GHG emissions globally to limit the temperature rise to only 2^oC (3.6^oF) above which will lead to catastrophe. The long-lasting and extraordinary threat of climate change can be mitigated via significant reduction of GHG emissions, which would require changes in the primary and secondary energy consuming infrastructure as well as would need a shift from the carbon-intensive fuels to low-carbon fuels or alternative carbon-free energy. However, it is argued that these changes will take a long time to occur and also the potential of the current technologies in mitigating the emissions is also questionable and controversial to reduce the emissions significantly in several coming decades (Hoffert *et al*., 2002; Pacala & Socolow, 2004).

The means of global heating are both the natural and human GHG emissions, but the part of man-made pollution is critical as they are mostly avoidable. The average temperature of the surface Earth increases due to increase in the concentrations of GHG and the chief culprit in polluting the environment is the amount of CO_2 in the atmosphere which also give rise to the sea level and global temperature (IPCC, 2005). The IPCC 5^{th} assessment report claims that "human influence has been detected in the warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes. This evidence for human influence has grown since the IPCC Fourth Assessment Report (AR4) and it is extremely likely (95–100%) that human influence has been the dominant cause of the observed warming since the mid-20th century" (IPCC, 2014). The theme of the anthropogenic climate change is the tragedy of commons where everyone has the equal right to exploit the resources, and no one is restraint from its use; it is because of this that the industries are polluting the atmosphere by disposing 90 million tons of waste products on daily bases. The researchers and institutions are trying to protect the environment from being more polluted by sharing the burden of resource protection whether these resources are common or emerging. The failure of discussions with the Intergovernmental Panel on Climate Change (IPCC) 2009 has called attention to a collective framework to address the use of the environment and to present incentives for a better sustainable world (Quilligan, 2010). Similarly, to circumvent the deleterious climate change, a global action plan has been set up among contributing parties in the shape of the Paris Agreement in the Paris Climate Change Conference held in November 2015, to keep the warming of the earth's environment below 2^0C (UNFCCC, 2016).

2.3 Theoretical Literature

The impression or idea that the climate of our planet can be changed by human activities has been observed as increasing gradually over more than the last hundred years. An idea which was fringed in the early twenties and late nineteenth century is close to a well know scientific consensus in the 21st century. This development of the notion is gripped by a science historian Spencer Weart in his book, "The Discovery of Global Warming" (Weart, 2003). The main theory which supports the climate change is the Anthropogenic Global Warming (AGW) theory. The AGW theory postulates that "man-made greenhouse gasses, mainly CO_2, methane, and nitrous oxides are responsible for the catastrophic warming trend globally since the Little Ice Age." The mechanism when it occurs is known as the enhanced greenhouse effect. Carbon dioxide is the second largest component of the greenhouse gasses after the water vapor and is responsible for up to 29% of the greenhouse effect. The concentration of CO_2 emissions in the atmosphere has almost become double due to the burning of fossil fuels and cutting of the forests throughout the world. The advocates of the AGW theory consider the man-made CO_2 emissions responsible for the catastrophes like floods, droughts, species extinction, the rise in temperature, severe weathers, different diseases, crop failures, and many other drastic changes all over the world. They are of the view that these disasters and catastrophes will become more frequent and the only way to stop them or at least reduce them is to cut down the man-made CO_2 emissions. It is argued that anthropogenic emissions will cause the global warming, and it can be divided into three parts. The first part is that the concentration of CO_2 emissions is increasing in the atmosphere, and the evidence is that the concentration of CO_2 has increased from 280 parts per million (ppm) to 380 ppm in the last 1000 years. The second part is that the current rise in the temperature is mainly due to anthropogenic CO_2 emissions and is proved as 57% of the emissions has increased the CO_2 concentration in the atmosphere and the rest 43% has been absorbed by the ocean and land biosphere. The third part is that CO_2 is a part of greenhouse gasses and doubling its concentration will result in the overall rise in the temperature of the world by 3^0C plus 1.5^0. The evidence provides to prove this was the work of Svante Arrhenius in 1986 when a rise of $4\text{-}6^0$ was observed for doubling the concentration of CO_2 emissions (Bast, 2010).

Economic growth is the predominant objective of the worldwide economies, therefore, the surety of this growth to be sustainable and environment-friendly is the order of the day. It is believed that human activities, including production, consumption, industrial activities, deforestation, transportation, and constructions among others are polluting the environment. To combat the problem of environmental pollution due to man-made CO_2 emissions, governments and organizations are trying to make very efficient use of the material and energy resources required for the above said human activities to keep up the pace of the economic growth in the higher quartiles and more environmentally sustainable. The efficient utilization of the natural resources in the economic activities by adopting modern technologies, transformation of the structure of the economy (from agriculture to manufacturing and further to services sector activities), and changes in the monetary policy and interest rate on loans can be helpful in reducing concentration of CO_2 emissions from the human activities. Following are some of the ways through which the concentrations of CO_2 emissions can be reduced.

2.3.1 Technological innovation

The theoretical background of the technological change can be traced back to the philosophies of Josef Schumpeter (1942) as cited by Fields (2004), who described that a new and superior technology enters the market in three stages namely invention, innovation, and diffusion. He argued that the process of "research and development" (R&D) be used to carry out the invention and innovation process of technology. Finally, the process of diffusion is conducted when a successful innovation is adopted by individuals and firms for its consistent use and is widely available for the use in appropriate applications. The collective impact of all these three either economic or environmental is called as the process of technological change. It is stated that technical change has a critical importance in describing the key environmental issues, mainly the long-term and large-scale environmental problems, including climate change (IPCC, 1995; Weitzman, 1997).

The uniqueness of information technology is not just in the field of decision-making and the system of knowledge management, but also has contributed in the fields energy efficiency and decoupling the material use. This has led to the expansion in economic activities without increasing impact on the quality of environment and has opened new ways for the development and improvements in new products and services. Therefore, environmental and sustainability related problem require a multidimensional approach that is interlaced with the natural system of the planet and global economy. Thus, a more informationally dense global economy where information technology can be used as a substitute for energy, raw materials, and other inputs, can be a more robust economy (Braden et al., 2001).

It is argued that the accumulation of capital is a necessary but not sufficient condition to maintain that the growth rates of the country in the higher quartiles on sustainable basis. It is necessary to involve innovation and technology in the process of growth to escape the dependence on the natural resources which are mostly pollution intensive in nature. The importance of the institutions and policies to promote innovation has been highlighted in the in economic theory and endogenous growth models (Guloglu & Tekin, 2012; Laeven, Levine, & Michalopoulos, 2015; Lucas, 1988; Romer, 1990; Tang & Tan, 2013). The secret of sustainable development lies in changing the nature and ways of attaining economic growth rather than limiting it. The continuation of economic growth in this limited world of resources is only possible via the advancements in the field of technology which can possibly provide and find the alternatives of the existing distinguishing resources. Technology is blamed to contribute to the problem of global warming by creating more pollution, but it can also be a source to solve the problem of environmental pollution. New ways to generate electricity and power can be helpful in replacing the old and traditional sources including, fossil fuels with renewable and environment friendly sources that are polluting the environment, thus, reducing global warming and climate change. Lack of technology can be one of the main sources of the difference in the development of the developed (more reliant on technology) and developing world (less dependent on technology).

The slogan ‘endogenous growth” emerged in the 1980s has clinched a diverse amount of theoretical and empirical work. The work on the endogenous growth separates itself from the previous work on the neoclassical growth by stressing that “*economic growth is an endogenous outcome of an economic system, not the result of forces that impinge from outside.”* The ‘New Growth Theory’ postulates two important points, first, it views that technological innovation or change is the product of economic activity which was previously treated as given or a product of non-market forces. The New Growth Theory is often known as “endogenous” growth theory due to the internalization of technology as a variable into a model of how market function. Second, unlike the physical objects, the theory holds that technology and knowledge have the characteristics of increasing returns which leads to the process of growth. This new theory emphasized on the fundamental question that, what is that make the economies grow: “*Why is the world measurably richer today than a century ago? Why have some nations grown more than others?*” The principal idea of the New Growth Theory is that knowledge is the driver of the growth. The ideas and knowledge are not something scarce and they can be shared and reused infinitely, and can be accumulated without any limit. The importance of technological innovation or knowledge in the growth scenario can be described as,*“ Ultimately, all increases in standards of living can be traced to discoveries of more valuable arrangements for the things in the earth's crust and atmosphere”*(Romer & Griliches, 1993, p. 345). Similarly,“ *No amount of savings and investment, no policy of macroeconomic fine-tuning, no set of tax and spending incentives can generate sustained economic growth unless it is accompanied by the countless large and small discoveries that are required to create more value from a* *fixed set of natural resource"*(Romer & Griliches, 1993, p. 345). The current study supports the inclusion of the technological innovation in the environment growth equation by the 'Endogenous Growth Theory'.

2.3.2 Structural Change

Structural change has gained importance in the economic theory since its origin (Quesnay, 1758; Turgot, 1766; and Steuart 1767). It is argued that the level of economic development is strongly related to the structural features of an economy (Adam Smith, 1776) while Ricardo (1817) is of the view that economic growth is near to impossible without changes in the composition of productive system. Although structural change has been described in many ways, but the furthermost definition is the persistent and long-term shift in an economy's share of the sectors (Chenery et al., 1986; Syrquin, 2007). More precisely, the adjustments over time in importance of different sectors according to the shares of employment or output is referred as structural change. It is argued that fast changes in the structural composition of economies are the soul carriers of economic growth in the modern era. Economic growth of the economies is due to the shift from basic production in the field of agriculture and mining to manufacturing and finally from traditional manufacturing towards more sophisticated form of manufacturing covering more skill and technology based activities. Kuznets (1971) listed structural transformation as one of the six main features of modern economic growth. Structural transformation has also received a lot of attention in the policy debate of developed countries where various observers have claimed that the sectoral reallocation of economic activity is inefficient, and calls for government intervention.

Structural change is the shift in the sectoral composition of GDP because of the transition of the economy from limited supply of technological change, thus, low-productivity and value-added gains towards an economy having full range of technological innovation, higher value-added expansion and high-productivity (United Nations Industrial Development Organization, 2013). In a broader sense "structural change" can be defined as a sectoral shift in an economy and advancement in technology in the process of production. Lowering the use of energy and input materials while using more efficient technology, will results in a decrease in the share of heavy industries, while the share of the services sector will boost. Thus, “structural change” can be defined as, “an increase in the knowledge-intensive and service-intensive forms of production at the expense of the traditional chimney industries (Jänicke et al., 1989). Structural change is considered as a striking and renowned empirical regularity in the process of growth. According to Schettkat & Yocarini (2006) structural changes in an economy can be explained by three factors: (i) a shift in the demand structure of all the final goods to services;(ii) inter-industry shift of labour towards more specialized services; or (iii) changes in the inter-industry productivity differentials.

The introduction of structural change in the environment growth equation is traced back to the ‘Lewis’s Structural Change Theory’ in 1955. The theory claims that the underdeveloped economy is divided into two sectors, the traditional rural subsistence sector, having surplus labor and the modern sector with high production where the labor is attracted from the first sector with labor surplus. Lewis argued that with an increase in the wages in the contemporary developed sector the labor will be attracted from the traditional overpopulated rural sector, thus, leading to economic growth and more employment in the modern sector. This shift towards modern sector, which is more industrialized and capital based will result in more energy use, which is needed for economic growth which can thus affect the quality of the environment.

The second model which can relate the structural change to growth and then ultimately environment is the ‘Structural Change and Pattern of Development’ model where in addition to the accumulation of human capital, there are other interrelated changes in the structure of the economy required to cause this transition to a modern one from the traditional economy. According to Islam, Vincent, & Panayotou (1999) and Panayotou (1997), three different structural forces can affect the environment: (i) the economic activity scale, (ii) the structure or composition of economic activity, (iii) the income effect on supply and demand of the efforts for abatement. These effects can be named after their impact on the environment: the level or scale effect, the composition effect or structure effect, and abatement pure income effect.

On the environmental side, the hypothesis of the structural change claims that the center of gravity of the economy can be shifted from agriculture, a low polluting, to a high polluting industry (Panayotou, 2000). Similarly, with a gradual rise in the economic growth of the country, it can be brought back to services economy which is less polluting. It is argued that environmental degradation is less when there is less development, as there would be less exploitation of the resources and limited ecological wastes. The stage of industrialization approaches when there occurs an increase in the intensity of agriculture and extraction of resources which leads to more waste generation and resource depletion. While as the economy grows and the pace of development increases, there occur a structural change from industrial phase to a more services based and information-oriented industries which can ultimately improve the environmental quality (Egli, 2002).

2.3.3 Interest Rate

It is well known that policies related to climate change are formulated based on the long-term goals. The need to preserve the primary ecosystem services for an extended period is conveyed via the term sustainability and intergenerational equity. It is the long-run cost-benefit analysis that made it necessary for the policy makers to consider the discount rate. The consumption preferences of the individuals and their alternative capital values over time accounts for the rationale behind the discounting of the future costs and benefits. The discount schemes due to the future costs and benefits play a significant role in predicting the climate change mitigation's potential efficiency (Sjølie, Latta, & Solberg, 2013). The role of interest rate in determining the inverted U-shaped relationship between income growth and pollutants via capital accumulation is very novel and is being ignored in the previous literature (Harbaugh *et al*., 2002). It is argued that the rate of interest or marginal rate of return on capital would be higher when the income level is low, as the individuals will satisfy their own needs and will invest in capital accumulation regardless of the negative externalities in the shape of pollution. On the other hand, when the income level of the country becomes high, the marginal return on capital (interest rate) goes down as there will be more willingness to pay for environmental betterment rather than saving. This delay option can be justified by considering the theoretical justification of environmentally friendly measures until the decrease in the rate of interest which alone may explain the initial increase in the pollution with the increase in the income and a downfall later with a further increase in the growth.

There are some policy tools which can reduce the environmental pressure because of economic progress. Two of the main policy tools experienced by Japan in its developing stage of the economy are mainly important in the reduction of environmental pollution. First policy tool is that of the low interest rate financing to those firms who are investing in pollution abatement projects. The second policy tool is the voluntary pollution control agreements (PCAs) [8]. The idea of charging low interest rate as a government policy to offer subsidies while charging interest rate in certain environment related sector by certain proportions to improve the development of those sectors is called interest rate discounts. It is argued that direct subsidies by government are far more burden in the shape of fiscal spending on the energy conservation, while low interest rates can be suitable alternative imposing a far low burden. Interest rate discounts can be used as a tool to leverage tool to inspire private investments in areas of interest such as green investments. A huge amount of investment can be attracted by the government by initiating the investment under the policy of low interest rate in areas of green investments to tackle the problem of environmental pollution and climate change.

The current study followed the first policy tool of low interest rate to investigate its impact on the quality of environment. The study followed the well-known Ramsey-Cass-Koopmans model developed by Ramsey (1928), theoretical framework elaborated by Cass (1965), and Koopmans (1965) to explain the inverse relationship between income and pollutants incorporating the role of interest rate. A clear example of the implication of the low interest rate on the environment related loans is that of Japan. The study will investigate the role interest rate in the income-pollution relationship to see whether the decrease in the rate of interest with the growth in income is able to explain the inverse U-shape relationship between economic growth and carbon dioxide emissions in the case of Malaysia. The current study is an effort to inspect whether the

[8] http://www.mofa.go.jp/policy/oda/summary/1997/07.html

low interest rate policy can be a part of the national and global policy in armory to tackle the local and global environmental pollution.

2.3.4 Economic Growth

The relationship between income and environment has evolved from the philosophy of the EKC- theory. The study of Kuznets (1955) claimed that the per capita income and income inequality move together with increasing path at the first stage of development, but the inequality starts decreasing after a point of development, called the turning point. This bell shaped curve is known as the Kuznets curve and was tested empirically by Grossman *et* al.(1991) and Grossman & Krueger (1995) for the first time in analyzing the relationship between environmental pollution and growth of income. The result of the study depicted an inverted U-shaped relationship same as the Kuznets curve between environmental pollution and per capita income. Moreover, the impact of economic growth on the quality of the environment is imitated from the work of Beckerman that, "*there is a clear evidence that, although economic growth usually leads to environmental deterioration in the early stages of the process, in the end, the best and probably the only way to attain a decent environment is to become rich*" (Beckerman, 1992:482). The Environmental Kuznets Curve (EKC) concept for the first time was originated by the economists involved in the trade and development, and their primary concern from this EKC concept was the international trade instead of the current economists who implement this concept in the field of environment in the context of pollution control. The EKC hypothesis has gained its theoretical foundations from the World Bank (1992) report and the study of Copeland & Taylor (2004).

The EKC has been presented with four main explanations by Copeland & Taylor, (2004). To create the preferred shape of the income-pollution relation and to show the emphasis of income by depicting the equilibrium pollution as a function of income these explanations put a restriction on the technology and preferences. The key feature of all the four mechanisms, namely (1) sources of growth; (2) income effects; (3) threshold effects; and (4) increasing returns to abatement have been isolated. Firstly, restrictions on the growth process all over the world could result in increasing and then decreasing part of the EKC, even when there is no environmental policy. Suppose in the early stages, there is an increase in the growth via capital accumulation (when the policy is not income responsive) and later on this growth is carried out by the attainment of human capital. The pollution will increase and then decrease due to the composition effect of income on the growth of per capita income. The composition effect dominates the scale effect by the assumption to eliminate the technique effect due to no policy response so that the pollution pattern can be determined by the changes in the sources of growth in this case. Alternatively, there are arguments in the favor of income effect, that is, due to the increase in income the shape of the EKC keeps on changing because the growth in income changes the demand for the environmental quality. Since environmental quality is considered as a normal good so when the income is low, the people prefer consumption of this common good over the environmental quality, and when there is an increase in the income the people are more willing to sacrifice the consumption to get a better environment. It is claimed that the pollution may increase due to very little or no effect of regulation on the abatement profitability. The pollution is supposed to decrease after reaching a threshold level due to the start or implication of policy, provided the imposition of proper assumptions on technology and tastes (Smulders, 2004). On the other hand, explaining the EKC phenomenon, it is argued that when there is an increase in the scale of the abatement, the efficiency of abatements will increase and will lead to a decrease in the pollution. The pollution may fall even if there is a stagnant policy because these efficiencies in the abatements make it more profitable (Copeland & Taylor, 2004).

2.3.5 Energy Consumption

It is claimed that an increasing population, higher material influence, and the higher living standards in large cities are causing an abrupt increase in the energy consumption and CO_2 emissions (Fong, Matsumoto, Lun, & Kimura, 2007, 2007a, 2007b). Similarly, it is reported that out of the total world energy use, fossil fuels are the main source to supply 80% up to 2040, as more than three-fourth of the world energy consumption will be met by liquid fuels, coal, and natural gas. The world energy-related CO_2 emissions will increase to 36 billion metric tons in 2020 as compared to 31 billion metric tons in 2010. Furthermore, these energy-related CO_2 emissions are projected to reach 45 billion metric tons in 2040 (U.S. EIA, 2013). With this much increase in the energy consumption, the amount of GHG emitted into the atmosphere will gear up and will lead to climate change. Thus, the government bodies, researchers, and environmentalists showed concern about rising GHG emissions in the atmosphere and started considering the problem by analyzing the relationship between the energy consumption and environmental quality.

To deal with the issue of energy and environmental pollution the study consults the "Decoupling Theory" which states that decoupling in its simplest form is to reduce the amount of energy resources such as fossil fuels and water used in the process of production, to delink the economic development from environmental degradation. The concept of decoupling by reducing the intensity of the energy resources in economic activities (resource decoupling) arrange for a foundation to enhance the human well-being and reducing their negative environmental impact (impact decoupling). This resource decoupling can be used to increase the resource using efficiency, called 'dematerialization' (UNEP, 2011). The dematerialization has been defined by the scholars in different ways. In the words of Herman *et al*. (1990) dematerialization is defined as a decrease in the materials use in production, and the amount of waste generated in the per unit of industrial products. The study used the decoupling theory to link energy consumption, economic growth and CO_2 emissions following the work of Fiorito (2013), Kalimeris *et al*. (2014) and Krausmann *et al*. (2009) among others.

2.4 Empirical Literature

2.4.1 Technological innovations and CO_2 Emissions

It is argued that two types of market failures pose hindrances to the development of environment-friendly technologies, namely a failure of the R&D market that leads to R&D underinvestment Arrow (1962), and environmental externality which does not allow for the incentives for the adoption of environmental-friendly technologies. Since the nature of the climate change problem is a long-run phenomenon, so it is argued that advancement in technology is a real factor in any solution. It is argued that if there are no policies to address the R&D market failure, still there will be some innovation even at a speed which is not desirable. Alternatively, no environmental mitigation will be there if there is no regulation to internalize the environmental externality. Therefore, it is stated that to solve the problem of climate change the second failure of internalizing the environmental externality is more critical than the failure of R&D market. It is claimed that the first market failure can be partially compensated by the technological push without taking into account the second failure. Thus, many researchers have addressed that it is hard for the R&D subsidies to work alone to improve the environmental quality (Fischer & Newell, 2004; Jaffe, Newell, & Stavins, 2005; Popp, 2006a; Schneider & Goulder, 1997). It is claimed that both the market failure related to diffusion of technologies and innovation and market failure associated with environmental pollution combined, provide a stable base for the selection of public policies that in addition to emissions reduction, help to foster the development and adoption of environmentally friendly technologies.

The 'induced invention hypothesis' presented by Hicks (1932, p. 132) supports that, if the incentive-based, emissions-control policies introduce carbon pricing, it is likely to affect the path and rate of the technological innovations. By this hypothesis some of the recent surveys looking into the economic models of environmental policy and the technological innovations focused on the need to include technological innovation as an endogenous variable instead of an exogenous process (Edenhofer, Lessman, Kemfert, Grubb, & Köhler, 2006; Loschel, 2002). It is documented that if the R&D subsidies supplement the carbon tax, this will result in an increase of seven percent in the welfare gains from the optimal carbon, which in turn can adequately support the socially-efficient research Popp (2004). The studies of Jaffe & Palmer (1997) and Brunnermeier & Cohen (2003) concluded that there exists a small but positive relationship between R&D investments and strict environmental regulations. Similarly, in a study Jaffe, Newell, & Stavins (1999) also observed a positive association between energy prices and innovation and further reported that these changes in the efficiency of energy use are mainly due to the autonomous change in technology. While on the other hand, the study of Popp (2001) claimed a strong positive relationship between energy-related innovations and prices of energy. The study of Smulders & Nooij (2003) argued that induced innovation is only able to mitigate the per capita income reduction, but cannot fully offset its effect due to the energy conservation policies.

Looking into the assessment of climate change which is the issue of energy and the environment in the long-run, the most critical assumption are concerning the nature and rates of change in technology (Yeh, Rubin, Hounshell, & Taylor, 2005). The literature also reveals that real GDP growth and energy consumption are the key determinants of environmental pollution (Ang, 2008; Azam et al., 2015; Saboori et al., 2014; Shahbaz et al., 2014). Energy consumption plays a vital role in the economic growth of the economy, and it also accounts for the CO_2 emissions because if the pattern of energy use is not efficient and most of the energy resources are non-renewable, it will emit GHG while used in the production process. The energy consumption can be improved and made productive via several methods, such as policies and controls, market-based approaches, but the due to its direct relationship with the energy efficiency function, the impact of technological innovation is gigantic. The nexus between energy efficiency and technological innovation is tested by Sohag et al. (2015), and the study revealed that the quality of production was increased by enhancing the energy efficiency through technological innovation. In addition, it is claimed that energy efficiency can be improved by technological innovation (Fisher-Vanden, Jefferson, Liu, & Tao, 2004; Gillingham, Newell, & Pizer, 2008; Hang & Tu, 2007; Zhou, Levine, & Price, 2010). In a similar way, it is argued that the energy efficiency is far greater in the OECD countries compared to other developing countries because of the substantial technological innovation. In addition, besides OECD economies, Malaysia has also experienced an inverted U-shaped relationship between the residential CO_2 emissions, and final consumption of the households due to the use of advanced household technologies. It is known that if the economy is unproductive, it will create more pollution, and this is because a more productive country uses its resources more efficiently compared to unproductive economies (Cole, 2004, 2007). In a study in the case of China Choi et al. (2012) concluded that in China most of the provinces do not care for the efficient use of CO_2, which results in variation in the CO_2 efficiency from 0.146 to 1, having an average of 0.645. Thus, it can be concluded that if the provinces follow the frontier of production technology, there would be on average, a CO_2 reduction of 35.5% in the 30 provinces.

It is argued that investments in R&D and change in technology are among other sources that can lead to reductions in the carbon dioxide emissions (Jones, 2002). In a group of studies Jones, (2002), and Vollebergh & Kemfert (2005) found that innovations enhance the capital and labor productivity which are crucial for economic growth. Similarly, an assumption that technological change is affected by the R&D investments is supported by the 'new growth theory' or induced technological change' literature (Vollebergh & Kemfert, 2005). Thus, it can be concluded that R&D investments and changes in technology are the common denominators of economic growth and CO_2 abatement. Moreover, it is found that investments in RERD&D are very useful in reducing the CO_2 emissions and their role in providing a base for investment, to develop targeted research policies, development, and demonstration is valuable in the climate change mitigation perspective (Mourshed & Quddus, 2009). In the same way, it is claimed that the stock of knowledge can be created through research centers and public universities, by funding them. The same can be done by aiding the private R&D by providing the subsidies and grants, i.e. the climate policy of upstream or technology-push (Nemet & Baker, 2009; Taylor & Rubin, 2008).

The study of Apergis, Eleftheriou, & Payne (2013) found that research and development expenditures affect the change in technology, economic growth and the costs of CO_2 abatement. The study also found the empirical support that CO_2 abatement will increase, and a reduction in the CO_2 emissions is noted due to the post-IFRS adoption of R&D spending. On the contrary, it is stated that if there occur a dramatic rise in the public expenditure on energy R&D, it may come at the expense of very high cost. It may be the cost that cuts the part of funds from other sectors, which is not desirable (Goulder & Schneider, 1999; D. Popp, 2006b; Yang, Oppenheimer, & Wilson, 2007). The findings provide support for existing criticism of energy subsidies because the costs exceed the benefits (Hymel, 2006). Similarly, based on the economic theory, there is no explicit justification for the current subsidy policy (Sheikh & Dec. 2010), and particularly in the case of traditional fuels (Metcalf, 2008).

Conversely, it is argued that the emissions are not influenced simultaneously by the U.S government spending on energy R&D (Karen Maguire, 2013). In a study to compare the welfare gains from technological innovation and optimal pollution control

(Carolyn Fischer, Parry, & Pizer, 2003) concluded that the welfare gains from optimal pollution control are better than the welfare advantages of the technological innovations. However, in a study Jaffe et al. (2005) concluded that R&D contribute to the reduction in pollution and also the welfare gains can be attained due to the creation of positive externalities by R&D. In addition, based on the disclosure quality and sustainability performance, Barth, Landsman, & Lang (2008), and Daske & Gebhardt, (2006) concluded that if there will be improvement in the emissions accounting disclosures, it will lead the firms to achieve their emissions reduction targets by developing green methods of transaction and green products via increasing the efficiency of their R&D expenditures. On the other hand, comparing the R&D subsidies with other emissions reduction policies, Fischer & Newell (2004) analyzed the emissions of U.S electricity sectors and concluded that R&D subsidies are ranked as the least effective policy among other emissions reduction policies. The study did not consider the knowledge spillovers effects and did not apply multiple policies simultaneously.

As discussed, there are several ways to improve the technology. Trade openness is one of the sources that facilitates the transfer of technology from developed countries to the developing countries of the world (Yanikkaya, 2003). Similarly, in a study of European Union Member countries, Wan, Baylis, & Mulder (2015) revealed that energy efficiency is improved via the diffusion of technology, and this diffusion is made through trade openness which makes it easy to transfer technology from one country to another. In addition, it is revealed that energy consumption is influenced by economic growth, trade openness, and human development in the economies of Indonesia, Malaysia, and Thailand (Azam, Qayyum, Zaman, & Ahmad, 2015). Similarly, energy consumption, among others affects the CO_2 emissions (Alkhathlan et al., 2012a; Ang, 2008; Shahbaz et al., 2011).

Based on the aforementioned discussion, the current study concludes to include the R&D expenditure or technological innovation in the environmental equation. The current study included the technological innovation in the equation due to the availability of data on technological innovation and not enough data on the R&D expenditures in the long-run relationship. The current study included the patent application as a proxy for technological innovation (Madsen & Andersen, 2010; Madsen, Ang, & Banerjee, 2010).

2.4.2 Structural Change and Environmental Quality

The structural change hypothesis laid the foundation of checking the impact of structural changes in the economy in environmental perspective. Different researchers adopting cross-section and country-specific studies have tested this hypothesis. According to Panayotou (2003) a transition of the process of production from a pollution-intensive industry to a less polluting or services sector economy based on information technology or any other change in the qualities of the structure of an economy may be included in the structural changes. This transition from pollution intensive to the information-based less pollutive economy can reduce the environmental degradation in the long-run. It is argued that changes in the structure of economy and energy efficiency can lead to improvements in final energy intensity. Similarly, structural changes like shifts in the production patterns i.e. from energy-intensive raw materials to less energy-intensive manufactured products can be helpful in reducing the energy intensity.

A strand of authors is of the view that structural change and technological advancement can play a vital role in attaining the pattern of environmental Kuznets curve (EKC) (De Bruyn et al., 1998; Dinda, 2004; Hettige et al., 2000; Shafik and Bandyopadhyay, 1992). A study conducted by IEA revealed that energy intensity in 11 OECD countries reduced by 1.6% per years due to energy efficiency and structural changes which account for three-quarters of the total decline (IEA, 2004, 2007b) as reported in (IEA, 2008). Regarding the Dutch classification of sectors, (Ang, 1993), adopted the decomposition analysis to emphasize on the sectoral classification of the SO2 emissions in West Germany and concluded that there are slight differences even if there are fully disaggregated classification. These finding failed to show the structural change as an important determinant to reduce the SO2 emissions when it was linked to EKC in both the countries in the 1980s. The work of Smulders & Bretschger (2000) also focused the structural change in achieving sustainable development. The study argued that rather than worsening the economy, structural change may be helpful in promoting the innovation and investments. It is argued that despite the increase in the incomes, the Netherlands and West Germany have experienced a fall in the SO2 emissions since the 1970s. Similarly, the study of López, Anríquez, & Gulati (2007) analyzed the relationship between environmental quality and structural change and concluded that even if there is no environmental policy, a movement of the structural change towards the non-resource sector will lead to sustainable growth.

It is claimed that the central truth of the developing societies is hidden in the large gaps that prevail between the modern and traditional parts of the economy regarding the labor productivity. The difference in the productivity performance of Latin America, Africa, and Asia is due to the pattern of structural change caused by a movement of labor towards high productivity from low-productive sectors in Asia. Similarly, the movement in Africa and Latin America from high-productive activities to low-productive sectors of the economy which can lead to changes in the environmental quality (McMillan & Rodrik, 2011). Similarly, it is argued that above a certain level of income, according to the EKC hypothesis, there are two primary mechanisms, namely the induced policy response and structural change that are used to reduce the pollution. It is argued that when economic growth is accompanied by structural change can have effects on the quality of the environment when there occur changes in the composition of economic activities, and a shift occurs from lower to higher pollution intensity or higher to lower. When the income levels are low, there is a tendency to shift from agriculture sector to the industrial sector, which is more polluting and will increase pollution. While on the other hand, when the income levels are higher, a significant shift will be from the industrial sector to the services sector, which is less polluting, and will lead to a decrease in the intensity of pollution. Therefore, this change in the industry share of GDP can be considered as the structural change (Panayotou, 2000).

In a study de Bruyn & Sander (2000) concluded that SO2 emissions in the Netherlands and West Germany have reduced in the 1970 to 1980 period. It is argued that the scale effect of growth was dominated by the reductions due to structural and technological effects during this time. Similarly, it is argued that the decrease in the emissions was more prominent in West Germany than in the Netherlands as the reduction due to technological changes was the same for both countries, but West Germany experiences an increase reduction in SO2 emissions due to the differences in the structural changes in both the countries. In a study in the USA, Tol et al. (2009) investigated the patterns of long-term energy consumption and CO_2 emissions from 1850 to 2000. The study observed that in the earlier part of USA's history the intensity of CO_2 emissions increase by 6.7% per year from 1850-1917 as the country switches from fuelwood to coal. The increase in the intensity of CO_2 emissions increased by 1.3% from 1917 to 1960 due to the transition from coal to oil and gas, which is much lower than the rise in the previous session. Similarly, in the later part, 1960-2002, technical and behavioral change, structural change, and fuel diversification from coal to oil and gas combinely has reduced the CO_2 emissions. In a recent study discussing the EKC evolution, Kaika & Zervas (2013b) claimed that income distribution, technical progress, the openness of trade, structural changes, energy efficiency, quality of institutions, good governance, and consumer preferences can be the possible causes of the inverted U-shape of EKC between income and environmental pollution.

On the other hand, a study of Bruyn & Sander (1997), while exploring the impact of structural change and international agreements involved in the reduction of SO2 emissions applied the decomposition analysis. The study concluded that structural change does not work as an important determinant of SO2 emissions in most of the developing countries in 1980's. Furthermore, in a study of China and India, Jayanthakumaran et al. (2012) investigated the relationship between economic growth, energy use, structural changes, the openness of trade and CO_2 emissions and concluded that there is no clear picture of the relationship between CO_2 emissions and structural changes in the economy. The study also confirmed the existence of the EKC hypothesis for India.

Last but not the least, the China's new model of development "new normal" has emphasized on the structural changes to achieve a lower economic growth of around 7% per annum for the next five years which is still strong relative to other countries. The aim of this model is to make sure the structural change has better social distribution quality and sound environmental impacts. The model has mainly focused on the shift from heavy industry to domestic consumption, service sector, and innovation to cope with the productivity demand and global value chain. Similarly, reducing the rural-urban regional inequalities and mainly to achieve the environmental sustainability to reduce GHG emissions and air pollution and other local environmental happenings that are causing damage (F. Green & Stern, 2015).

2.4.3 Interest Rate and CO_2 emissions

It is well understood that discount rates play a vital role in determining the economics of climate change which is the event of distant-future, but unfortunately when the future discount rates are unknown it is unclear to find out the present value of the future events. However, the decision regarding the selection and application of an appropriate long-run real rate of return on capital for discounting in the long-run has remained very controversial and uncertain. This uncertainty and controversy about discounting the distant future is not only relevant to academic researchers, but is critically important to policy makers to formulate policies for climate change. The kind of discount rate, which the government applies to evaluate policies and projects in different time periods is known as the social discount rate. This social discount rate has been provided with many rationales, including the social opportunity cost of investment, market interest rate, and consumption rate of interest (Lind, 1982; Pearce & Ulph, 1999). The governments of the UK and France use a schedule of the discount rate, that decline over time, to analyze the costs and benefits of the future projects (Lebegue, 2005; HM Treasury, 2003).

Different models select different discount rates, and these differences account for the variations in the social cost of carbon (SCC) estimates (Tol, 2005). It is stated that there has been a common use of the traditional constant discount rates in the past, however, it is argued that using the standard discount rates the projects of climate change mitigation often fail to meet the cost-benefit criterion in the long-run (Almansa et al., 2011; Almansa & Requena, 2007; Evans and Kula, 2011; Yang, 2003). The most recent studies emphasized for the use of time-varying discount rates, more precisely a decreasing discount rate is appreciated to handle the climate change and other long-run problems (Groom et al., 2005). The declining discount rates are used with different rationales such as to use a hyperbolic function to replace exponential discount factor. It is argued that compared to conventional discounting, the declining discount rate causes an increase in the weight placed on the future values (discount factor). The discussions of Groom et al. (2005), and David Pearce (2003) provided support for the use of declining discount rates both on theoretical and empirical grounds. The most evident example of the declining discount rate is the application of a discount rate, which declines over time in the UK HM Treasury (2003) Green Book, which is used in policy making. The uncertainty theory presented by Newell & Pizer (2003) is considered as the base for the Green book recommendations. They analyzed the effects of uncertainty by using the interest rate data of US for two centuries under random walk method and noted that SCC becomes almost double by the application of this scheme to *Dynamic Integrated Climate-Economy (*DICE) model (Nordhaus & Boyer, 2000; Nordhaus, 1991; Nordhaus, 1994).

The Stern Review argued for 1.4%, while some conservative economists advocated the use of discount rates between 3% and 5%, and in the last but not the least a discount rate of 1% to 2% was suggested by (Johnson & Hope, 2012). The high discount rates of 2.5%, 3% and 5% based on the market interest rates advocated by the Working Group, argued to avoid the obligation to particular values and were criticized by (Johnson & Hope, 2012). This criticism was due to the reality that the costs of climate change, including starvations due to damages to agriculture and the loss of human lives, are difficult to be measured in economic terms. The study also argued that the cost of human life and sufferings are neglected entirely if the discount rate is 3%. The work of Weitzman (2007) which concluded a 1.7% discount rate, is also supported by Johnson & Hope, (2012) for the SCC values and range of suggested discount rates. In addition, Evans & Kula (2011) suggested that the application of the lower discount rates should be about the carbon values but not of the monetary values. They were of the view that there will be an increase in the scarcity of the environmental values with the economic growth, therefore, looking for the discount rate by the social time preference, the economic growth should be free of such values. The consumption discount rate of 4.3% preferred by Nordhaus when applied to the DICE model gives an emission reduction of 14% in 2015, the reduction was estimated to be 25% in 2050, and in 2100, it was noted to be 43% (Nordhaus, 2007). On the other hand, if the same DICE model applies the rate of 1.4% preferred by Stern would lead to a reduction of CO_2 emissions by 53% in

2015. There are also differences in the optimal prices of both Stern and Nordhaus due to the difference in the consumption discount rate as the optimal price for a discount rate of 1.4% is $360/ton of carbon and $35/ton for a discount rate of 4.3% in 2015.

Arguing about the discount rates, based on the theory that only those projects are ensured to be worthwhile if they are discounted at a market rate of return, the positivist supports the discounting of the future climate change on the market rate. They are of the view that if we will save for the future and will invest in low-returning, the project will lead to resource wastes, so to save more for future, the only way is that there will be a decrease in the market rate of return, which interacts with the two effects. Thus, the evaluation of the project needs to be on the basis of the market rate of return if the objective is the more saving for the future (Sunstein & Weisbach, 2008). In addition, it is argued that as the costs and benefits of the capital projects are long spread over time, and the economic analysis of these projects requires the cost-benefit analysis to be discounted to the present value. Since there is an inherent relationship between the capital stock and pollution, as capital has two sub-parts, one is non-polluting due to the use of green technologies and the other part is the capital stock polluting the environment by exploiting the fossil fuels and non-renewable energy sources. The most dominant of both the capital stocks is the polluting capital stock due to the maximum use of non-renewable energy sources like coal, oil and gas all over the world. Furthermore, since the capital stock is related to interest rate so the variations in the rate of interest will affect the polluting capital stock, thus affecting the pollution level (Di Vita, 2008a, 2008b; Rashid & Sharma, 2008). The present study takes into consideration real interest rate to investigate the impact of changes in the interest rate over time on the environmental pollution by targeting the polluting capital (energy consumption).

2.4.4 Economic Growth and CO_2 Emissions

Environmentalist and policy makers have focused on the relationship between environmental quality and economic growth due to the importance of the sustainable development and a cleaner environment. The per capita GDP, mainly represents the economic growth, and CO_2 emissions are used to symbolize the environmental pollution. A strand of literature also investigated the presence of EKC relationship between income and pollution by incorporating quadratic term of income per capita (Coondoo & Dinda, 2008; Dinda & Coondoo, 2006; Dinda, 2004; Heil & Selden, 1999; Managi & Jena, 2008; Shahbaz, Lean, & Shabbir, 2012; Stern, 2004). Some other studies, including Grossman & Krueger (1995), Zarzoso & Morancho (2004), and Selden & Song (1994) among others, have investigated the presence or absence of EKC and validated it for the income and emission. Different researchers have opted to find out the existence of EKC in various studies including country specific and panel studies having more than two countries, and these studies are different from one another in methodological context. It is claimed that differences in the time periods, indicators, research samples, models, lack of long period data, countries natural features, technological conditions, culture, history, and socio-economic conditions are possible the reasons to alter the results of the studies carried out for EKC (Xingjun Ru *et al*., 2012).

In the case of country-specific studies investigating the existence of EKC the study of Jalil & Mahmud (2009) applied the autoregressive distributed lagged (ARDL) model to analyze the data on income, energy consumption, trade, and CO_2 emissions for a period 1975-2005 of China. The results revealed that income and carbon dioxide emissions have a quadratic relationship between them, which is the evidence in the support of EKC hypothesis. In the same way applying a bit different econometric technique of flexible nonlinear parametric and semi-parametric models, He & Richard (2010) supported the evidence of EKC in a more robust way. Moreover, the study also noted that the progress towards the environmentally friendly technology in Canada is primarily driven by the oil shocks of the 1970s. Moreover, the existence of EKC in Spain was analyzed by Esteve & Tamarit (2012) by applying the threshold technique to the data over a period 1957-2007 to find out the relationship between per capita income and per capita CO_2 emissions and the study concluded a non-linear relationship between the variables indicating the existence of EKC in Spain. Similarly, investigating the long-run relationship between endogenous structural breaks, economic growth, trade openness, energy consumption and CO_2 emissions, Jayanthakumaran, Verma, & Liu (2012) concluded that there exists the EKC hypothesis in India. In a country-specific study if India, Boutabba (2013) analyzed the data on financial development, carbon emissions, energy consumptions, economic growth and trade to investigate the causal directions and long-run equilibrium relationship between the variables. Applying a multivariate estimation technique, the study depicted the presence of a causal and long-run relationship between per capita income, square of real per capita income, financial development, trade openness, energy consumption, and CO_2 emissions. Furthermore, the presence of EKC hypothesis is validated in the Indian economy. Similarly, analyzing the causal link between carbon emissions, trade, economic growth, financial development, and energy consumption in Turkey, Ozturk & Acaravci (2013) utilized the data over a period 1960-2007 and concluded a long-run relationship between the variables. The study also found that the EKC hypothesis holds in the case of Turkey between economic growth and CO_2 emissions.

On the other hand, in a study of Turkey for a period 1992-2001, Akbostanci *et al*. (2009) applied cointegration techniques to investigate the relationship between environment and income by analyzing the data on per capita income and CO_2 emissions. In the long-run a monotonically increasing relationship was found between income and CO_2 emissions and the second part of the study for panel data found an N-shaped relationship between the set of pollutants like PM10 and SO_2 and income. Similarly, Fodha & Zaghdoud (2010) analyzed the time series annual data of Tunisia on CO_2 emissions, Sulfur dioxide (SO2) emissions, and GDP per capita for the period 1961-2004 to estimate the long-run relationship. The results confirmed that the variables are cointegrated in the long-run. There was found no support for the EKC hypothesis for GDP-CO_2 emissions, but the study found the presence of EKC hypothesis for GDP-SO2 emissions. Furthermore, Alkhathlan, Alam, & Javid (2012a) took the data of Saudi Arabia to investigate the short and long-run relationships between GDP, CO_2, energy consumption and employment ratio by applying ARDL and VECM Granger causality tests. The study shows that the variables are cointegrated in the short and long-run. The study reported a positive, and significant influence on economic growth by elasticity coefficients of energy consumption, employment ratio and CO_2 emissions in the long-run. The VECM causality test shows no causality running from energy consumption per capita and CO_2 emissions per capita towards GDP per capita. The study reported a causal relationship from employment ration towards GDP in the short-run. The study argued that there will be no harm to GDP per capita by adopting energy conservation and CO_2 control policies in Saudi Arabia in short-run. However, the long-run income elasticity may lead to an increase in the CO_2 emissions because of more income. Furthermore, in the case of Nigeria, Akpan & Akpan (2012) investigated macroeconomic data covering the period 1970-2008 to estimate the causal and long-run association between economic growth, CO_2 emissions and electricity consumption. The study employed a Multivariate VECM framework, and the results show that increase in CO_2 emissions and GDP are cointegrated in the long-run and CO_2 emissions are increased by increasing the electricity consumption showing that the growth process is pollutant intensive in Nigeria. The results of the Granger causality test indicate unidirectional causality running from GDP to CO_2 emissions showing that CO_2 reduction policies are not harmful to GDP in Nigeria. The study supported no EKC hypothesis and found no causality between electricity consumption and GDP, which leads to the importance of investments in the electricity sector in Nigeria to develop the electricity infrastructure.

Focusing on the panel studies, involving many countries, the study of Tamazian & Rao (2010) examined the data of 24 transition economies for the relationship between GDP and environmental degradation and concluded that EKC hypothesis is supported. The study also reported that environment is favorably affected by financial development and institutional quality and argue that without having quality institution the financial openness may hurt the environment. Similarly, in a study of 12 MENA (the Middle East and North African) countries, Arouri *et al*. (2012) analyzed the relationship between real GDP, energy consumption, and CO_2 emissions. The study concluded that CO_2 emissions are positively and significantly affected by energy uses and the relationship between economic growth, and CO_2 emissions are quadratic in the long-run. In addition, Fuinhas & Marques (2012) applied the ARDL bound testing and VECM Granger causality approach to finding out the long-run relationship and causal relationship between economic growth and energy use for Italy, Portugal, Turkey, Spain, and Greece. The empirical results supported the feedback hypothesis and also the ARDL test confirmed the presence of a long-run relationship. Furthermore, Arouri*et al*. (2012) extended the work of Ang (2007), Apergis & Payne (2009), Liu (2005), and Payne (2010b) by applying the Bootstrap Panel Unit Root Test and techniques of cointegration for the data of 12 MENA countries. Their study found out the CO_2 emissions, energy consumptions and GDP relationship for the period 1985-2010. The results argued that CO_2 is affected significantly and positively by energy use in the long-run and the results also reported that there occur a quadratic relationship between economic growth and CO_2 emissions. The long-run coefficients of the study confirm the presence of EKC hypothesis and also a difference in the turning point of different countries was noted differently. Furthermore, investigating the major factors affecting CO_2 emissions, the impact of GDP, energy consumption, foreign direct investment and total trade in 12 MENA countries, Al-mulali (2012) analyzed the data over a period 1990-2009 and concluded that all the factors cause an increase in the CO_2 emissions. Looking into the causal relationship between income and environment, Ghosh (2009) used the data on CO_2 emission and GDP in India to find out the causal link between the variables by including employment and investment as additional determinants of CO_2. The results concluded that there is no causal relationship between GDP and CO_2. Dinda & Coondoo (2006) also studied the data on income and emission and presented ambiguous results. In addition, Ghosh (2010) explored the causal relationship between GDP and CO_2 for India by including employment and investment as the new determinants of CO_2, but there was no causality found between income and CO_2 emissions.

The studies above have investigated the validity of the EKC hypothesis between environmental quality and some determinants including per capita income, energy consumption, the ratio of openness, and financial development etc. Some of these studies supported the existence of the EKC hypothesis while some have rejected and did not find the inverted U-shaped relationship between CO_2 and income. Recently, various studies using the cross-sectional data also have validated the EKC (Lean & Smyth, 2010; Pao & Tsai, 2011; Pao & Tsai, 2010) among others. However, most of these studies ignored the magnitude, significance, and signs of the coefficients. The panel data studies also have some problems of countries individual heterogeneity. Therefore, some studies adopted the time series techniques to remove the country specific heterogeneity problem and to check for the EKC. Similarly, using the time-series data some researchers have validated the presence of the EKC (Ang, 2007, 2008; Fodha & Zaghdoud, 2010; Halicioglu, 2009; Nasir & Ur Rehman, 2011; Ozturk &

Acaravci, 2010; Shahbaz *et al*., 2013; Tiwari *et al*.,2013). The current study focused on the country specific time series data to analyze the relationship between per capita income and environmental quality by applying the EKC approach.

2.4.5 Energy Consumptions and CO_2 emissions

The use of natural resources like coal, gas, and oil among others, made easy the process of development. These are the energy resources that have enabled the world to trigger up the process of economic growth because every production process involves the energy consumption. Energy consumption is considered as a primary ingredient in the economic growth and the development of any economy around the world. The studies related to economic growth, CO2 emissions and energy consumption may be divided into four groups according to causal relationship. The first group is composed of studies which show the unidirectional causal relationship running from energy or electricity consumption to GDP both in aggregate and disaggregate level, e.g. the studies of Lee & Chang (2005) in Taiwan covering the period 1954-2003, Soytas & Sari (2003) and Altinay & Karagol (2005) for Turkey; France, Japan and Germany respectively. Similarly, Shiu & Lam (2004) for China for a period 1971-2000; Morimoto & Hope (2004) for Sri Lanka for the period 1960-1998 and Wolde-Rufael, (2004) for the period 1952-1999 in Shanghai found unidirectional causalities. Second, there are also some studies which show unidirectional causality from economic growth towards energy consumption or electricity. The most known of them are Cheng (1999) for India over a period 1952-1995, Ghosh (2002) for India for the period 1950-1997. Third are those studies which found bi-directional causalities between energy consumption and economic growth. Researchers in this string of literature are Soytas & Sari (2003) for Argentina, Oh & Lee (2004) in case of Korea over a period 1970-1999, Yoo (2005) covering a period 1970-2002 again for Korea, Ghali & El-Sakka (2004) for Canada, and Jumbe (2004) in Malawi for a period 1970-1999. The fourth group of the researcher is those who found no causal relationship between economic growth and energy or electricity consumption. The most common of them are Stern (1993) for the period 1947-1990 in the USA, Cheng (1995) for the period 1947-1990 in the US, and Yu & Hwang (1984) for the period 1947-1979 in the US.

In the context of country-specific studies, Alam et al. (2012), in the case of India examined the data on GDP, energy consumption and energy-pollutants to find out the link between these variables. A bi-directional causal relationship was reported by the study in the case of CO_2 and energy consumption while the study reported a neutrality hypothesis between economic growth and CO_2 emissions. Furthermore, Alam et al. (2012) again investigated the data of Bangladesh for the causal relationship between economic growth, energy consumption, and CO_2 emissions. The study employed the ARDL bound testing approach and VECM causality tests to find out the long-run and causal relationship. The empirical results concluded the presence of long-run equilibrium relationship. The results also reported the feedback hypothesis between energy consumption and CO_2 emissions and a unidirectional causality was reported to run from CO_2 emissions to economic growth. Similarly, Soytas & Sari (2009) analyzed a study in Turkey covering the period 1960-2000 to determine the co-integration and applied Toda-Yamamoto technique for causality. The study argued that there runs a unidirectional causality from CO_2 to energy consumption. In addition, Chang (2010) examining the causal relationship between energy consumption, GDP and CO_2 emissions in China by applied the multivariate causality technique and concluded that energy consumption is Granger caused by GDP, which leads to CO_2 emissions. While studying the data of South Africa Menyah & Wolde-Rufael (2010a) arrived at a conclusion that energy consumption causes CO_2 emission, and CO_2 emission Granger caused the economic growth of the country. Moreover, (Lotfalipour et al., 2010) investigated the causal relationship analyzing the data of Iran on economic growth, fossil fuels, and CO_2 emission over a period 1967-2007 by applying the Toda-Yamamoto method and concluded that economic growth is caused by gas consumption. In the same way, Hatzigeorgiou et al. (2011) analyzed the data from Greece for the period 1977-2007 by applying the multivariate co-integration analysis and argued that there is a unidirectional causality running from GDP to energy intensity (EI) and CO_2 as well. The study also reported the bidirectional causality between EI and CO_2. In a study Jafari et al. (2012) tested the relationship between economic growth, energy use, and CO_2 by including urbanization and capital as the potential determinants of energy-pollutants and energy consumption and argued that urbanization causes energy consumption, and there is no long-run relationship found between the variables.

Furthermore, Soytas & Sari (2009) and Ozturk & Acaravci (2010) reported that no causal relationship between energy consumption and economic growth. Similarly, Menyah & Wolde-Rufael (2010a) argued that the problems of climate change and energy security be believed to be solved by the use of renewable energy resources. However, there was no causality found running from renewable energy to CO_2 emissions mean that CO_2 emission is not helped by renewable energy consumption. Most of the studies support the feedback hypothesis by arriving at long and short-run bi-directional causality and also reported the long-run relationship between the variables (Apergis, Payne, Menyah, & Wolde-Rufael, 2010; Apergis & Payne, 2010a, 2010b, 2010c). Similarly, Tiwari (2011) in the case of India concluded that GDP is increased by a positive shock given to RES consumption, and it decreases the CO_2 emissions. The study also reported that the impact of a positive shock to GDP is very high on the CO_2 emission in the case of India. Similarly, Al-mulali, (2014) analyzed the data from 30 major nuclear energy consuming countries for the period 1990-2010 using the panel mode to find out the influence of nuclear energy consumption on economic growth and CO_2 emissions. The study concluded positive long-run effect of nuclear energy consumption on GDP, but no long-run effect on carbon dioxide emissions. The study also revealed a short-run negative causality from nuclear energy consumption towards carbon dioxide emissions and also reported a positive causality running towards GDP.

On the other hand, it is argued that there be no causal relationship present between Carbon emission, petroleum products, fossil fuels and economic growth in the case of Iran Lotfalipour et al. (2010). Moreover, Kulionis (2013) analyzed the data from Denmark for the period 1972-2012 by applying the multivariate framework to test the causal relationship between renewable energy consumption, GDP and CO_2 emissions. The study employed Johansen co-integration and Granger causality and Toda-Yamamoto approach to finding out the long-run and causal link between the variables. The empirical results of co-integration test concluded no co-integration relationship and the causality tests reported that a unidirectional causality run from renewables to CO_2 emissions. The study also reported a neutrality hypothesis between economic growth and renewable energy which concluded that conservation hypothesis will not influence the economic growth significantly. The study also revealed no causality between GDP and CO_2.

In the context of panel studies, Mahadevan & Asafu-Adjaye (2007) used the data from Malaysia and Singapore among other countries for a period 1971-2002 by applying the multivariate VAR approach and found that there is a bi-directional causality running between energy consumption and economic growth both in the short and long-run. However, Ang (2008) found mixed and contradictory conclusions about the conservation policies in Malaysia in the long and short-run. In the same way, Chontanawat, Hunt, & Pierse (2008) used the data from more than 100 countries and concluded that in 35% of the poorest countries, 42% of the middle-income and 69% of the high-income countries economic growth is caused by energy consumption. In the same way Huang, Hwang, & Yang (2008) found that there is no causality between energy use and economic growth in low-income economies while in the case of middle and high-income countries, and the study reported that economic growth causes the high energy use. Examining the data of 22 OECD countries Lee, Chang, & Chen (2008) found a bi-directional causality between energy consumption, economic growth and capital stock and also reported a long-run causality towards economic growth from energy consumption. In the same way Apergis et al. (2010) studied the panel data of 19 developed and developing countries to find out the causal relationship between nuclear energy consumption, CO_2 emissions, economic growth and renewable energy expenditures by constructing a panel error correction model covering the period 1984-2007. The study concluded that there exists a bi-directional causality in short-run supporting the feedback hypothesis between renewable and nuclear energy and economic growth. The results also reported that there is a unidirectional causality running from nuclear and renewable energy consumptions to GDP in the long-run, thus supporting the growth hypothesis.

Investigating the relationship between real income and per capita renewable energy Sadorsky (2009) used oil price and CO_2 emissions as control variables for G7 countries covering the period 1980-2005. The study used the Pedroni approach to cointegration in panel data Pedroni (2000, 2001) and Granger causality tests. The study concluded that per-capita renewable energy consumption is affected positively and significantly by RGDP, and it is negatively affected by the oil prices by a smaller amount. Moreover, Menegaki (2011) examined the data of 27 European countries for the period 1997-2007 to find out the causal relationship between renewable energy and economic growth. The study adopted the multivariate panel framework and included the final energy consumption, employment and greenhouse gas emission as additional variables using a random effect model. The study reveals that there is no direction of Granger causality between economic growth and renewable energy both in the short and long-run. The study also concludes that economic growth cannot be promoted to the lower level of renewable energy use in the European countries. Investing the panel data of 14 MENA countries over a period 1990-2011, Omri (2013) applied the simultaneous-equation models and reported a bi-directional causality between economic growth and energy consumption. The study also concluded a unidirectional causality from energy consumption to CO_2 emissions and a bi-directional causality between economic growth and CO_2 emissions for all countries. The study suggested that the sustainable economic growth can be achieved by recognizing the differences between economic growth and energy nexus in the MENA region. In addition, Sari & Soytas (2009) examined the data of 5 selected OPEC countries, including 2 MENA countries (Saudi Arabia and Algeria) covering the period 1971-2002 to find out the relationship between income, CO_2 emissions, energy and total employment. The econometric framework adopted was that of ARDL, and the results concluded that there is a long-run relationship between the variables in Saudi Arabia. The paper found that there is no need for these countries to slow down their economic growth to control the CO_2 emissions. Similarly, in a study Apergis & Payne (2014) investigated the data of 7 Central American Countries covering the period 1980-2010 to examine renewable energy consumption determinants. The study found long run cointegration relationship with positive and significant coefficients between real GDP, renewable energy consumptions, CO_2 emissions all in per capita form, real coal prices, and real oil prices. The study observed the effect of Energy and Environment Partnership with Central America, to increase the renewable energy sources, in the shape of a structural break in the long-run relationship in 2002. The study showed that the influence of per capita renewable consumption on real oil and real coal prices is strengthened in the post-2002 period than the pre-2002 period by adopting the vector error correction model in the nonlinear panel smooth transition phase. The study also reported that real GDP per capita is more sensitive to CO_2 per capita.

Concluding the discussion, the studies of Ozturk (2010) and Payne (2010) stated that the causal relationship between economic growth and energy use has been focused in most of the studies, as both are the core determinants of CO_2 emissions, but these studies failed to have clear conclusions about the relationship. It is argued that the failure may be due to climate conditions heterogeneity, among other things, different economic development stages, the difference in energy use patterns different time periods and different approaches of Econometrics adopted. Therefore, this study opted for the long-run and causal relationship between the variables to explore the clear causal and long-run relationship.

2.5 Literature from Malaysian Perspective

In a study for Malaysia and France Ang (2007, 2008) analyzed the data on GDP, energy consumption, and CO_2 emissions and concluded that GDP growth causes energy consumption and CO_2 emission. A unidirectional causality was found running from economic growth towards energy consumption. Similarly, Chiou-Wei *et al*. (2008) applied bivariate approach to the data of Malaysia during the period 1971-2003 and reported the conservation hypothesis support and suggested the implementation of conservation policies without harming the economic growth. In a study in Malaysia, Ang (2008) analyzed the annual time series data for the period 1971-1999 to find out the long-run equilibrium relationship between energy consumption, real per capita GDP and CO_2 emissions. The empirical results confirm the presence of a long-run relationship between the variables of the model. The results showed positive short and long-run association between CO_2 and energy consumption. Applying a different methodology, Islam *et* al. (2011) investigated the data of Malaysia to find out the long-run relationship between economic growth, population, energy consumption and financial development by adopting the ARDL approach. The VECM Granger causality approach was applied to the causal link, and the results concluded that both in the short and long-run economic growth and financial development influence the energy consumption and the population energy relation is validated only in the long-run.

In a study in Malaysia Azlina & Mustapha (2012) applied vector error correction models and cointegration technique to investigate the long-run and causal relationship between economic growth, energy consumption, and CO_2 emissions and concluded that there exist long-run relationship economic growth, energy use, and environmental pollution during 1970 to 2010. Their study also revealed the existence of unidirectional causality that runs from CO_2 emissions to energy consumption, pollutant emissions to economic growth and also from economic growth towards energy consumption. Similarly, in a study in Malaysia Ismail & Yunus (2012) investigated the long-run and causal relationship between economic growth, energy and CO_2 emissions including trade as an additional variable. The study concluded the presence of long-run causalities between economic growth, energy, and CO_2 emissions, and also among emission, energy, capital and exports. The study also reported that short-run non-causality tests and concluded that short-run causalities are running from economic growth towards the capital, from energy use to economic growth and capital, and also from CO_2 emissions to exports. Since the study observed a feedback hypothesis so long-run policies are suggested to be focused.

In the same way, Mugableh (2013) reinvestigated the time series annual data of Malaysia for the period 1971-2012 to find out the relationship between energy use, CO_2, and GDP. The study found the long-run equilibrium relationship between the variable using ARDL approach. The study also checked the EKC hypothesis for economic growth and CO_2 emissions per capita. The study indicated the presence of a long-run relationship between the variables. Focusing on the financial development and environmental quality Shahbaz *et al.* (2013) conducted a study in Malaysia to investigate the influence of financial development on the environmental quality. The study applied ARDL bound testing approach to finding out the existence of the long run relationship between the variables and concluded that more investments are attracted due to the development of the financial sector. This further leads to more industrialization, thus, a higher amount of energy consumption, which obviously will increase the CO_2 emission, thus increasing CO_2 emissions. Reinvestigating the environmental Kuznets curve (EKC) hypothesis in 5 ASEAN countries, Chandran & Tang (2013) incorporated some new variables and evaluate the impact of foreign direct investment and energy consumption in the transportation sector on environmental pollution. The study applied cointegration technique and Granger causality test to find out the long-run and causal link between the variables. The results reveal that the variables are cointegrated in three out of five countries namely Malaysia, Thailand and Indonesia and CO_2 emissions are significantly increased due to transportation sector energy consumption while the impact of FDI is not significant. The study did not find the EKC hypothesis to be supported in Malaysia, Thailand, and Indonesia. Furthermore, the causality results reveal that in the long-run a bidirectional causality runs between economic growth and CO_2 emissions in Indonesia and Thailand. The study also found a unidirectional causality running from GDP to CO_2 emission in Malaysia and a bidirectional causality between energy consumption of the transport sector, FDI and carbon dioxide emissions in Malaysia and Thailand. There are some other researchers who emphasized on the relationship between energy consumption, economic growth and environmental quality, and concluded that economic growth and energy consumption are the main determinants of environmental pollution in Malaysia (Ang, 2008; Azam *et al.*, 2015; Saboori *et al,*. 2014; Shahbaz *et al.*, 2014).

More recently, in the case of Malaysia, Lau *et al*. (2014) empirically observed the environmental Kuznets curve both in the short and long-run, adopting trade openness and foreign direct investments for a period 1970-2008. The results from bound tests and Granger causality tests validate the presence of EKC between CO_2 emissions and GDP both in short and long-run. Analyzing the impact of different determinants of energy consumption in Malaysia, Indonesia, and Thailand Azam *et al*. (2015) claimed that FDI and economic growth increase the energy consumption in all the three countries. On the other hand, the study concluded that in the case of Malaysia energy consumption is boosted by the population growth while energy consumption is decreased with an increase in the population growth in Indonesia. Similarly, the study also concluded that trade and human development index increase the energy consumption in Malaysia, Indonesia, and Thailand. Similarly, in the case of Malaysia Begum *et al.* (2015) investigated the energy consumption, economic growth, and population growth to measure their dynamic impact on the environmental quality. The study applied ARDL approach to determine the cointegration between the variables over a period 1970-2009 and concluded that in the early stages the CO_2 emissions falls with an increase in the GDP growth from 1970 to 1980 but it starts rising after 1980 until 2009 thus rejecting the EKC hypothesis. Furthermore, the results revealed that both economic growth and energy consumption lead to an increase in CO_2 emissions in the long-run and there is no significant impact of population growth on the CO_2 emissions.

2.6 Summary of Literature Review

Many studies have focused on the relationship between GDP, energy consumption, and CO_2 and some other studies included further potential determinants of CO_2 emissions. However, all the studies have different results. Some of the related studies showed a positive relationship between the CO_2 and its determinants while others supported the negative relationship between the variables. Some studies showed that there is a long-run relationship between CO_2 emissions and its determinants while other studies supported the presence of a short-run relationship. Some studies focused on the causal relationships and supported the bidirectional causality relationship while others embark in favor of unidirectional causal relationship, and even some studies show that there is no causal link between carbon dioxide and some of its determinants. Some studies focused both the long-run and causal relationship and supported the presence of both while others argue against it. Based on the aforementioned literature, it is concluded that the relationship between the variables is not conclusive and need more research. This difference may be due to the econometric techniques used, the study period, the omitted variable biases and the country's economic and development stage and many other reasons. The issue of CO_2 and environmental degradation is a long debated and hot issue, but it is still controversial and need to be investigated more.

Aside from this, the current study focused the CO_2 emissions and its determinants because even after having a voluminous literature on the topic, there are some areas or aspects not yet explored properly. A lot has been published on the relationship between economic growth and CO_2 emissions, energy consumption and CO_2 emissions, international trade, and environmental quality. Variables such as international trade, and population among others have been used to determine their impact or relationship to the environment. But, there are still some areas like structural change, technological innovation and interest rate, which has not been focused that much until now.

The role of structural change is very much necessary as the country moves from one mode of production to another, the preferences in the field of consumption also change. Since Malaysia has moved on from the basic agricultural economy to a more industrial based economy, and now towards a more services-based economy, so, the role of structural change must not be ignored. The study, thus, included the structural change as an independent variable and this study is the first of its kind in Malaysia because there is no prior study investing the impact of structural change in the environment.

In the case of technological innovation and research and development expenditures, the county would like to invest more in the technological innovation or research and development to find out which technology is better for the country in the case of environmental protection. The role of technological innovation has been explored in the previous studies investigating its role in different areas like economic growth, energy consumption, and trade, but there is no prior study in the case of Malaysia investigating the impact of technological innovation on the CO_2 emissions.

Similarly, the role of the interest rate has not been so much emphasized as a determinant of CO_2 emissions in the literature. Some studies focused on discounting the future damages of the climate change as this is a long-run phenomenon, and emphasized on the role of discount rate (Almansa & Martínez-Paz, 2011; Cropper *et al.,* 2014; Drupp *et al*., 2015; Foley *et al.,* 2013; Kula & Evans, 2011; Rashid & Sharma, 2008; Robson, 2013; Williams & Goulder, 2012). There is no clear conclusion that which discount rate or the interest rate should be used. Thus, the current study adopted the real interest rate to investigate its role in the environmental perspective as the literature has the clue that interest rate influence the polluting capital, which in turn, affect the environment. Thus, the current study included the role of real interest rate to investigate its role in the income-pollution equation. The current study is an effort to fill the above-mentioned gap in the literature in the environmental perspective in the context of Malaysia.

Table 2.1: Literature Review Summary of different study variables

Name of Author	**Countries**	**Time period**	**Variables**	**Co-integration**	**Causality**
(Alam *et al*., 2012)	Bangladesh	1972-2006	ELC, EC, CO_2, and RGDP	Yes	EC ↔ CO_2 CO_2 → GDP
(Shahbaz *et al*., 2012)	Malaysia	1971-2008	FD, CO_2, EC, GDP	Yes	Feedback Hypothesis b/w Variables
(Silva *et al.* 2012)	USA, Spain, Portugal, Holland	1960-2004	RES-E, CO_2, GDP	No	Conservation hypothesis
(Tugcu *et al*., 2012)	G7 Countries	1980–2009	NREC, REC, GDP	Yes	Feedback Hypothesis
(Anees *et al*., 2012)	Pakistan	1971-2007	EC, GDP, ID, OPEN, Agr.G, Ur	Yes	GDP → CO_2, EC CO_2 → GDP, ID, Agr. G
(Kulionis, 2013)	Denmark	1972-2012	REC, GDP, CO_2	No	REC → CO_2 Neutrality Hypothesis
(Shafiei & Salim, 2014)	OECD Countries	1980-2011	POP, CO_2, GDP,EC,REC	Yes	Feedback and Conservation

Table 2.2: Discount/Interest Rate and CO_2 emissions

Author	Country	Topic	Conclusions
(Groom *et al.*, 2005)	UK	Declining discount rates: the long and the short of it	Declining discount rates are appropriate for long-run problems like climate change
(Stern, 2006)	USA	What is the economics of climate change	Supported the declining discount rate for long-term projects
(Hepburn & Koundouri, 2007)	Scotland	Recent advances in discounting : implications for forest economics	Declining discount rates are favorable for long-term phenomenon
(Rashid & Sharma, 2008)	Canada	Interest Rates and Environmental Pollution	Interest rate variations affect the environmental quality
(Drupp *et al.*, 2015)	A survey	Discounting disentangled: an expert survey on the determinants of the long-term social discount rate	92% Experts agree on the social discount rate in a range of 1% to 3% (low discount rate).

Table 2.3: Structural changes and Environmental Pollution

Author	Country	Topic	conclusions
(Ang, 1993)	West Germany	Sector disaggregation, structural effect, and industrial energy consumption: an approach to analyzing the interrelationship.	Structural change is not a significant determinant to reduce SO_2 emissions
(Smulders *et al.*, 2011)	West Germany and Netherlands	Economic Growth And The Diffusion Of Clean Technologies:Explaining Environmental Kuznets Curves	Endogenous innovation, infrastructural changes and policy-induced shifts in technology improves environmental quality
(Jayanthakumaran *et al.*, 2012)	India and China	CO_2 emissions, energy consumption, trade and income: A comparative analysis of China and India.	No clear relationship between structural change and CO_2 emissions
(F. Green & Stern, 2015).	China	China ' s " new normal ": structural change , better growth , and peak emissions	Structural change is an important determinant of quality social distribution and sound environment

2.7 Research Gap Identification

The problem statement of the study discussed that environmental pollution due to higher economic activities is a big problem in Malaysia and the temperature in Malaysia is increasing gradually due to the increase in the concentration of CO_2 emissions that is a significant threat to the economy and environment in Malaysia. In the light of previous literature, the study focused on the carbon dioxide emissions because the country is very prone to the impact of climate change as a slight rise in the temperature will disturb the pattern of rain, crops, droughts, floods and the sea level will rise which will endanger the lives in the coastal areas. Empirical studies have focused on the problem of CO_2 emissions in Malaysia by investigating different determinants of CO_2 emissions in the case of Malaysia. The literature review discloses a change in the approach to handle the problem of environmental pollution with the passage of time and it can be seen in the most recent studies. The literature review section also reveals that different studies have focused different models or theories to investigate the determinants of CO_2 emissions. There are also some novel trends adopted in recent literature that focus on the differences in the methodological approaches to investigate the problem. Moreover, there is a broad appreciation of the contextual change, time, and country-specific studies to instigate the problem on a wider scale to add value to the literature. Last but not the least, applying a different and proper methodological approach, changed from the previous studies can give rise to more practical, robust, and different results compared to previous studies conducted. To cope with these steps, the current study identifies the gaps in the determinants of CO_2 emissions where there is a need for further research.

A wide strand of literature emphasized on the need of the technological innovation to be included in the growth-environment equation. Based on the comprehensive literature review the study identified that the work on the technological innovation in environmental perspective is very novel and has not been emphasized before. The work done on the technical innovation in the prior studies has utilized changed proxies or even a most recent study used the patent applications as a proxy for technological innovation to find out its impact on the energy consumption. Previous studies have focused on the role of R&D expenditures to measure the technological innovation while the current study focused on a different and superior measure of technological innovations in terms of a number of patent applications in the country. More recently, the study of Sohag et al. (2015) in the case of Malaysia investigated the impact of technological innovation on the energy consumption. The current study is even different from the study of Sohag et al. (2015) as it focused on the role of patent applications to investigate its impact on the environmental quality which is the first of its type. The literature reveals that the use of technological innovation (patent application) to minimize CO_2 emissions can improve the environmental quality, and this can be true in the case of Malaysia that is in the state of transition and is focusing on the vast application of technology.

The literature also discloses that Malaysia is a fast-growing economy and has moved from the traditional agricultural practices to a more industrialized economy, so, there is a dire need to emphasis the impact of structural changes on the quality of environment. No prior study in the Malaysian context has focused on the role of structural change in environmental perspective. Furthermore, the relationship between the environmental quality and structural changes overall the world is inconclusive. The current study emphasized on the role of structural change to investigate the case study of Malaysia regarding the relationship between the transitions from agriculture to industrial, and then to services based economy (structural change) and CO_2 emissions.

Based on the previous literature the study also found a gap related to the role of interest rate in the income-pollution equation. There has been a very little focus paid to this aspect of the interest rate and there is a very limited literature available. The general perspective is that the inclusion of interest rate can influence the income-pollution relationship by affecting the polluting capital and can lead to the validation of the EKC hypothesis. To fill the research gap, the current study used the real interest rate to investigate its impact on the environmental quality as it is argued that interest rate can influence the polluting capital and thus environmental quality. The application of real interest rate to the environmental pollution has been suggested by researchers, but has not been used in any study in Malaysia and the literature in the global context is very limited. The study used population growth and foreign direct investment as control variables to fill the gap of omitted variable biases. Based on the literature, most of the studies in Malaysian context have used small sample sizes and focused on some determinants of CO_2 emissions. The current study used a large sample and covered annual data from 1971 to 2013 as per the data availability. The present thesis also filled the gap related to the use of multi-theoretic concept as the study used different theories, namely anthropogenic global warming theory, Lewis's structural change theory, the structural change hypothesis, endogenous growth theory, the EKC hypothesis, decoupling and dematerialization theories among others to support the hypothesis of the study. The current study also found a gap in the methodological aspect in Malaysian context and tried to fill this gap by applying proper tests of unit root to investigate the data stationarity, the ARDL cointegration technique to check the long-run association, and Granger causality test of a causal relationship. The study covers the previous studies gap related to the problem of endogeneity by applying ARDL cointegration to control for the problem of endogeneity. The study applied Robust Least square techniques for robust cointegration results of ARDL, which are rarely used.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

A general strategy, adopted while conducting research that summarizes the way of the research to be conducted and identifies the methods and techniques used to attain the results among other things is called research methodology. The methods adopted in methodology are used to define the mean or modes of the collected data or, sometimes, it shows how to calculate a specific result (Howell, 2013). The prime objective of this methodology chapter is to provide the theoretical and empirical basis, philosophical assumptions and research methods to underpin the study. The focus of the current chapter is to highlight the conceptual framework, the data used, the macroeconomic variables involved in the study, the research activities, the strategy to carry out research, empirical methods, and research techniques to conduct this study.

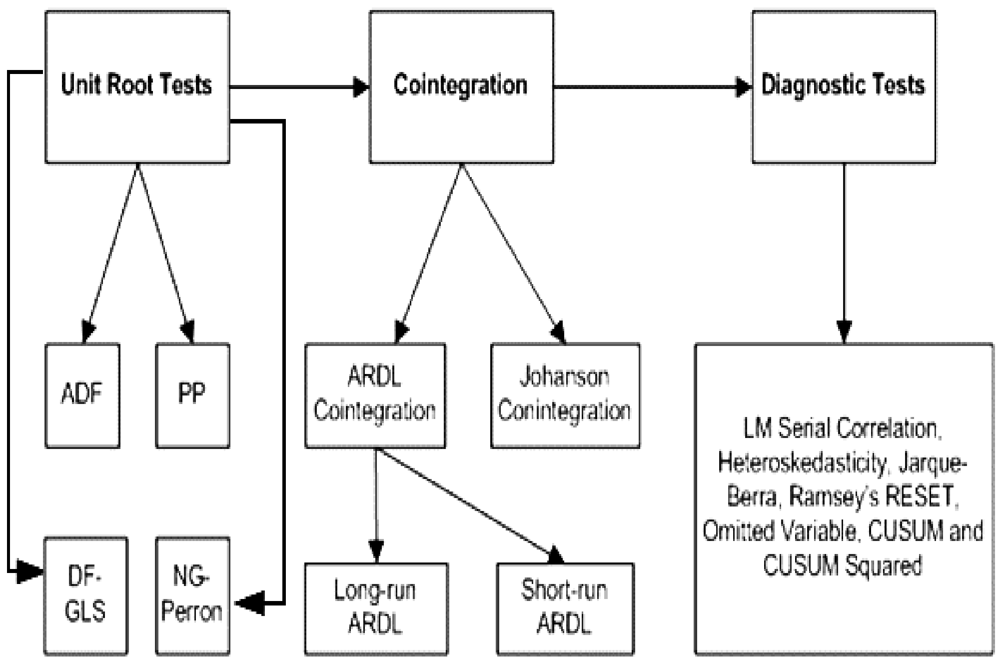
3.2 Research approach and design

The data used in this research is time series and secondary in nature, and the study applied a quantitative approach to estimate the regression. The study includes statistics and relevant analytical methods to accomplish the objectives. Quantitative research is a "formal, objective, systematic process that can test and describe the relationships and can observe the variable's cause and effect interaction (Carter & Porter, 2000). Similarly, the quantitative research method is used "to describe variables, to examine relationships among variables, and to determine the cause-and-effect interaction between variables" (Burns & Grove, 2005:23). Furthermore, the quantitative research methods are “techniques associated with gathering, analysis, interpretation and presentation of numeric information” (Teddlie & Tashakkori, 2009:05).

This study aims to find out the long-run and causal relationship between CO_2 emissions and its determinants. Similarly, the study seeks to determine the existence of Environmental Kuznets Curve in the case of Malaysia in the presence of aggregated and disaggregated form of energy consumption. Furthermore, the study aims to achieve the objective of investigating the relationship between technological innovation and environmental quality. The study also aims to determine the impact of structural change on the environmental quality in Malaysia. The study further seeks to investigate the role of real interest rate and polluting capital in income pollution relationship in environmental perspective. The study used the regression analysis to achieve the objectives by applying unit root tests to achieve the stationarity level of the variables. The study applied the ARDL bound testing approach to find out the long-run relationship between the study variables. The ARDL approach is used to investigate the long and short-run estimates of the model.

Regression analysis is a “statistical tool to investigate the relationship between variables” (Sykes, 1993). It is argued that regression technique is applied to a set of data when a researcher wants to find out the relationship between dependent and independent variables. Similarly, it is used to determine the causal relationship between the variables. The use of regression analysis has been long in the field of Econometrics to find out the relationship and causal effects between the variables (Huffman, Hoffman, Huffman, & Hoffman, 2005). Many researchers in the field of research to estimate and forecast the relationship between the study variables have adopted regression methods. Begum et al. (2015) used regression analysis and adopted ARDL bound approach to investigate the relationship between CO_2 emissions, energy consumption, economic growth and population growth in Malaysia. Similarly, Saboori & Sulaiman (2013b) also employed regression analysis to find out the relationship between environmental degradation, economic growth and energy consumption for Malaysia by and applied ARDL bound testing approach. On the other hand, Alshehry & Belloumi (2014) used the regression analysis and adopted the Johansen multivariate cointegration approach to investigate the dynamic causal relationship between economic growth, energy consumption and energy prices in Saudi Arabia. Moreover, Heidari *et al*. (2015) used regression analysis and adopted the panel smooth transition regression (PSTR) to investigate the relationship between economic growth, energy consumption and CO_2 emissions in five ASEAN countries. Based on the above literature the study employed ARDL and Granger causality techniques to accomplish the objectives of the study. The research methodology design and process of the current study are given in Figure 3.1.

Figure 3.1: Research Methodology Design and Process



3.3 Data Collection and Statistical Validity

The contemporary study analyzed secondary data to investigate the long-run relationship between the variable of the study. Secondary data can be referred to data or information that has been already gathered by someone other than the researcher itself conducting the present research. Such data can be accessed via the Internet, publications and libraries, and can be internal and external to the organization (Sekaran, 2003). Similarly, according to Blaike (2003), "the data that has already been collected by someone else for a different purpose" is called the secondary data. There may be some secondary sources to gather this type of data, some of them are government publication, statistical bulletins, published and unpublished information either from outside or inside the organization, the internet, previous research, library records, case studies and online databases, among others (Sekaran, 2003). The use of the secondary is very vital in research in the fields of social sciences, particularly in the field of economics as the researchers look for the historical impacts of different macroeconomic variables on each other to estimate their present effect and to forecast their incidence in the future. The period for this kind of research can be longer as the data are available for decades and so on. This type of data is inexpensive and can be easily obtained. The current study obtained the data for analysis from the World Bank data source, World Development Indicators (WDI), Department of Statistics Malaysia (DOSM), Ministry of Finance (MOF), Index Mundi Malaysia, British Petroleum (BP), International Energy Agency and Energy Information Administration (EIA).

The study emphasized on the data regarding the determinants of CO_2 emissions in Malaysia from 1971 to 2013. Malaysia has been a great supplier of the primary products such as tin, palm oil, rubber, liquefied natural gas, and timber, to the developed and industrialized countries since the late nineteenth century. The diversification of the Malaysian economy from basic agricultural activities towards more manufacturing and industrial activities which involves a huge amount of energy consumption that emit carbon dioxide in the atmosphere started in about 1970. The manufacturing industries such as textiles, rubber products, electrical and electronic products, which are export-oriented, took the driving seat in the development of the country in 1970s. The country has successfully moved from the heavy dependence on the agriculture and primary commodities via the implementation of the 'multi-sector agglomeration' development strategy. This agglomeration strategy has at first brought in the 'horizontal diversification', which alter the pattern of growth from primary commodities to other sources of growth, which are more manufacturing and industry based. The second phase of this diversification was the vertical diversification which focused on the commodity-based value chain with higher value-added industries. The third stage was the locational diversification, where disperse manufacturing activities in different corridors have been selected rather than to focus on some specific centralized location. The diversification of manufacturing mostly occurred during the study period from 1970 onwards which lead to boom in the economic growth in the country, thus causing pollution, and the country was recognized as newly industrialized economy in 1990s. Currently the country is looking to achieve the 2020 vision, thus, the focus is on the high rate of economic growth and the country is involved in different economic activities which are polluting the environment. Thus, the study emphasized on the data period is from 1971 to 2013 as this is the longest dataset available in Malaysia.

The data used in the research is taken from the World Development Indicators (WDI, 2015), and it covers the data on most of the required variables from 1971 to 2013. The study collected the data on real gross domestic product (GDP) per capita as a proxy for economic growth (Begum et al., 2015; Chandran Govindaraju et al., 2013; Saboori & Sulaiman, 2013a; Saidi & Hammami, 2014; Salahuddin & Gow, 2014; Sohag et al., 2015). The study incorporated carbon dioxide emissions per capita for environmental pollution as CO_2 emissions cover most part of the greenhouse gasses released into the atmosphere causing pollution (Azlina et al., 2014; Begum et al., 2015; Chandran Govindaraju & Tang, 2013; Saboori & Sulaiman, 2013a). Data on total energy consumption (EC) was collected in the shape of energy use in kg of oil equivalent per capita (Adib Ismail & Yunus Mawar, 2012; Alam et al., 2015; Begum et al., 2015; Pao & Tsai, 2011a). The study also emphasized on international trade or trade openness and included the trade as percent of GDP (Trade%) (Farhani & Ozturk, 2015; Farhani et al., 2013; Naranpanawa, 2011; Shahbaz, Khan, & Tahir, 2013; Sohag et al., 2015). The study includes increase in population (Pop) in the model following the studies of Begum et al. (2015), Lelieveld *et* al. (2015), and Theodore (2006). The present study also includes the proxy for structural change in the economy (Beck, 2005; D. Bruyn & Sander, 1997; Jänicke, 2004; Pasche, 2002; Kaivo-oja et al., 2014; Luukkanen et al., 2015). The study used the industry value added (INVAD) as a proxy for structural change following the work of Suri & Chapman (1998), McMillan & Rodrick (2011), Luukkanen et al. (2015). The study also focused on the advancement in the field of technology to investigate its impact on the environmental quality and used the number of Patent Applications (PA) as a proxy for technological innovation (Popp, 2001, 2004, 2005; Sohag et al., 2015). It is argued that patent data has some advantages while studying the environment-friendly role of the technological changes as it can provide with the advances in the technological fields which are narrowly defined and also can track the diffusion of technology on the basis of the application for patents by investors in different countries (Popp, 2005). The study focused on the patent application data rather than R&D data because it can provide a complete detail of the each invention, identify the inventor's home country, provide the description of the invention, and can facilitate the researcher with earlier patents.

The current study also emphasized on the role of interest rate to tackle the problem of increasing CO_2 emissions and used interest rate following (Newell & Pizer, 2003; Groom et al., 2007; Li et al., 2015). Furthermore, Karanfil (2009) and Shahbaz, Qazi, & Tiwari (2013) mentioned interest rates to be used as a control variable in the future studies. The current study employed real interest rate (RIR) following the work of Di Vita (2008b), Nordhaus, (2011), and Rashid & Sharma (2008).

3.4 Sources of Data Collection

The current study used secondary and time-series data to analyze the long-run and causal relationship between the variables of the study and used the data covering different periods of time for different models due to the availability of data. The study collected the annual time series data from the World Development Indicators (WDI) a World Bank database, Department of Statistics Malaysia (DOSM), Bursa Malaysia (Index Mundi), British Petroleum (BP), and the Carbon Dioxide Information and Analysis Center (CDIAC). The study collected data on environmental degradation in terms of CO_2 emissions per capita, real GDP data in the form of GDP at constant 2005 US$, and square term of real GDP for the EKC purpose. Data on energy consumption was taken in the form of energy use kg of oil equivalent per capita, trade openness was measured in terms of trade as a percent of GDP, and financial development was included in the study in the form of broad money (M2). The study considered two variables, namely population growth and foreign direct investments (net inflow) as control variables in the analysis to cover the problem of omitted variables in the model. The variable used as a proxy for structural change is industrial value added and that for technological innovation is the number of patent applications. The data on the interest rate is taken in terms of real interest rate. Furthermore, the data on a set of variables like energy consumption, electricity consumption, coal consumption, gas consumption, and oil consumption is collected from British Petroleum (BP), US Energy Information Administration (EIA) and International Energy Agency (IEA) for a period 1981-2013. The study collected annual data based on the previous studies in the same field.

The study converted all the data in the logarithmic form because the problem of heteroscedasticity can be reduced due to log transformation of the data by compressing the variable measurement scale (Gujarati, 1995). The variable for the real interest rate (RIR) is taken in the normal form without converting it into a logarithmic form. The transformation of the variables in the logarithmic form is also in line with the previous studies (Begum et al., 2015; Karanfil, 2009; Li et al., 2015; Saboori & Sulaiman, 2013b; Muhammad Shahbaz, Khan, et al., 2013; Sohag et al., 2015; Tamazian & Bhaskara Rao, 2010). According to Azlina et al. (2014), the time-series policy variables are converted to the logarithmic form in the process of a model estimation to facilitate the unit root tests and differences. Furthermore, the actual model is converted into a logarithmic form for final estimation. The required objectives, data variables, nature of data, sources of data collection, and the methods applied to analyze the data and achieve the objectives are shown in the following table.

Table 3.1: Objectives, variables, data sources, nature of data and methods of analysis

Objectives	**variables**	**Data sources**	**Nature and Type**	**Methods of Analysis**
To investigate the impact of technological innovation on the environmental pollution (CO_2)	CO_2, EC, GDPpc, GDP^2, TI, Trade	WB and CDIAC	Annual, Secondary, and Time series	Unit Root Tests, ARDL Cointegration, ARDL long-run, Short-run, Diagnostic Tests.
To explore the impact of structural changes in the economy on the environment in Malaysia	CO_2, EC, GDPpc, GDP^2, Invad, Trade, Pop	WB, and CDIAC	Annual, Secondary, and Time series	Unit Root Tests, ARDL Cointegration, ARDL long-run, Short-run, Diagnostic Tests.
To determine the role of interest rate in the income-pollution relationship in Malaysia	CO_2, EC, GDPpc, GDP^2, RIR, Trade	WB, CDIAC	Annual, Secondary, and Time series	Unit Root Tests, ARDL Cointegration, ARDL long-run, Short-run, Diagnostic Tests.

3.5 Theoretical Framework

The impression or idea that the climate of our planet can be changed by human activities has been observed as increasing gradually over more than the last hundred years. This development of the notion is gripped by a science historian Spencer Weart in his book, "The Discovery of Global Warming" (Weart, 2003). The main theory which supports the climate change is the Anthropogenic Global Warming (AGW) theory. The AGW theory postulates that "man-made greenhouse gasses, mainly CO_2, methane, and nitrous oxides are responsible for the catastrophic warming trend globally since the Little Ice Age." The concentration of CO_2 emissions in the atmosphere has almost become double due to the burning of fossil fuels and cutting of the forests throughout the world. The advocates of the AGW theory consider the man-made CO_2 emissions created by humankind responsible for the catastrophes like floods, droughts, species extinction, the rise in temperature, severe weathers, different diseases, crop failures, and many other drastic changes all over the world.

The current study compliments the AGW theory by incorporating some macroeconomic variables like economic growth under the EKC theory (hypothesis) which postulates that at low per capita income a further increase in per capita income will lead to an increase in the concentration of CO_2 emissions, reaching the peak point and then a further increase in the per capita income will decrease the environmental pollution. Similarly, the current study also emphasized on the role of energy consumption under the Decoupling or Decarbonization theory to complement the AGW theory which states that decoupling in its simplest form is to reduce the amount of energy resources such as fossil fuels and water used in the process of production, to delink the economic development from environmental degradation. Furthermore, the present study incorporated the financial development in the equation under the light of "Endogenous Growth theory" which shows that economic growth can be significantly affected in the long-run by the development of financial sector via technological innovations, investments in human capital (financial development) and knowledge.

It is claimed that trade can affect the environmental quality by two dominant hypotheses namely race-to-bottom hypothesis and the gains-from-trade hypothesis (Frankel & Rose., 2005). The study included trade openness in the model under the Heckscher-Ohlin (1919) trade theory to complement the AGW theory by targeting environmental pollution. The H-O theory postulates that countries with more capital will export capital-intensive goods and will be importing the labor-intensive capital and vice versa which can increase or decrease environmental pollution accordingly. Similarly, the study focused on the role of technology in the growth model under the Endogenous Growth Theory to complement AGW theory in the environmental perspective. The New Growth Theory or the "endogenous" growth theory due to the internalization of technology as a variable into a model of how market function. Moreover, unlike the physical objects, the theory hold that technology and knowledge have the characteristics of increasing returns which leads to the process of growth.

The introduction of structural change in the environment growth equation is traced back to the 'Lewis's Structural Change Theory' in 1955. The theory claims that the underdeveloped economy is divided into two sectors, the traditional rural subsistence sector, having surplus labor and the modern sector with high production where the labor is attracted from the first sector with labor surplus. This shift towards modern sector, which is more industrialized and capital based will result in more energy use, which is needed for economic growth which can thus affect the quality of the environment. Similarly, the hypothesis of the structural change claims that the center of gravity of the economy can be shifted from agriculture, a low polluting, to a high polluting industry (Panayotou, 2000). Similarly, with a gradual rise in the economic growth of the country, it can be brought back to services economy which is less polluting. The present study further focused on the role of interest rate under the well-known Ramsay-Cass-Koopmans Theorem and Rybczynksi Theorem where both the theorems postulates that fluctuation in the interest rates can influence the environmental quality by affecting the polluting and energy intensive capital.

3.6 Econometric Modeling and Hypothesis of the Study

The study formulated a total three models and based on the literature support to achieve the desired objectives.

3.6.1 Model 1: The impact of Technological Innovations on the Environmental Quality

Endogenous growth theory was the first to consider the technological innovation as an endogenous factor to affect the production. The introduction of technology as an endogenous factor open the ways for better economic growth and efficient energy consumption. Different studies used the technological innovation or research and development expenditures in different contexts to evaluate different dependent variables for measuring CO_2 emissions, energy consumption, and economic growth (Buonanno, Carraro, Castelnuovo, & Galeotti, 2001; Chèze, Chevallier, & Gastineau, 2013; Goulder & Schneider, 1999b; Greaker & Pade, 2009; Parry, 2003; D. Popp, 2005; Sohag et al., 2015; Taylor & Rubin, 2008). The current study used patents applications and not the research and development expenditures due to the availability of the data for research and development expenditures only from 1996 onwards which is not sufficient to find out the long-run relationship. In the previous literature, some studies look for the relationship of technological innovation with environmental quality and other variables, but used different proxies other than patent applications. Furthermore, in the case of Malaysia Sohag *et al*. (2015) used technological innovation in terms of patent application to explore its impact on the energy consumption. There is no study until the present in the context of Malaysia that has taken the proxy of patent applications for the technological innovation to find out its impacts on carbon dioxide emissions. This study is different even from the most recent study of Sohag *et al*. (2015) in the context of the dependent variable as they measure the impact of economic growth, technological innovation and trade openness on energy consumption, while the current study used energy consumption, economic growth, its squared term, and trade openness to explore its impact on the environmental quality. The study derived the CO_2 emission function from the Endogenous Growth theory of Romer where the production function can be written as:

$$Y = A(R)\, f\,(R_i, K_i, L_i) \tag{3.1}$$

Where Public stock of knowledge from research and development (R) is represented by *A*, R_i represents the results from the research and development expenditure stock. Ki denotes the stock of capital of a firm, and L_i is used to represent the stock of available labor in the firm. Romer considers the research technology as an endogenous factor as the new knowledge is thought to maximize the profit of the firm, thus we the aggregate production function can be written as:

$$Y = f(A, K, L) \tag{3.2}$$

Where *Y* is the aggregate real output, *K* represents the capital stock, *L* is the stock of labor, and *A* represents technological advancement. The Study replaced the abbreviation for technological advancement (A) with (TI) as technological innovation. Since the environmental quality is affected by economic growth (GDP) which is the real output of an economy, so the CO_2 emission function can be written as follows:

$$CO_2 = f(Y) \tag{3.3}$$

Thus, we can say that:

$$CO_2 = f(TI, K, L) \quad (3.4)$$

Since capital K can be divided into two sub-parts, where one is pollution emitting capital like burning of fossil fuels and energy including oil, gas, coal and electricity etc. and the other is a non-emitting capital, including renewable energy resources, so

$$K = K_e + K_{ne} \quad (3.5)$$

Where K_e is considered as the non-renewable energy resources (EC) as they emit a large portion of GHG in the atmosphere and K_{ne} is the non-emitting capital, so the CO_2 emission function can be written as follows as only emitting part of capital is responsible for environmental pollution.

$$CO_2 = f(TI, EC, L) \quad (3.6)$$

Furthermore, the *L* represents the labor activities which can be replaced by economic activities thus GDP. So the CO_2 emission function will become as follows:

$$CO_2 = f(TI, EC, GDP) \quad (3.7)$$

The study included the squared term of GDP to check for the validity of EKC of the model. Similarly, there is enough literature evidence that international trade can attract modern technology in the guest country and trade and technology can evolve side by side. It is argued that change in energy-saving technology can arise both from domestic innovation activities and the diffusion of foreign technology (Bosetti, Carraro, Massetti, & Tavoni, 2008; Hall & Helmers, 2011; Popp, 2001, 2006; Verdolini & Galeotti, 2011). On the other hand, there is enough theoretical and empirical literature on the relationship between international trade and quality of environment. It is evidenced that trade can affect the quality of environment (Andersen et al., 2010; Ang, 2009; Carson, 2009; Demiral, 2016; Farhani, Chaibi, & Rault, 2014; Sharma, 2011).

$$CO_2 = f\left(EC, GDP_{pc}, GDP^2, TI, FD\right) \quad (3.8)$$

The conversion of the CO_2 emission function into an econometric model and taking the log of both sides make it easy for estimation (Alam *et al.*, 2015; Begum *et al.*, 2015; Pao & Tsai, 2011; Saboori & Sulaiman, 2013b; Muhammad Shahbaz, Sbia, *et al.*, 2014). Thus, the study converted the econometric model into logarithmic form as follows.

$$lnCO_{2t} = \beta_0 + \beta_1 lnEC_t + \beta_2 lnGDP_t + \beta_3 ln(GDP_t)^2 + \beta_4 lnTI_t + \beta_5 lnFD_t + \epsilon_t \quad (3.9)$$

Where ϵ is the error term, *TI* denotes technological innovation, and *FD* is used to represent trade openness. The current model covers a period 1985-2013 due to the availability of data on patent application from 1985 onwards for Malaysia. The hypothesis of this model of the study based on the literature is as follows:

H_1: **H_0: Technological innovation will reduce the concentrations of CO_2 emissions in Malaysia**

H_A: Technological innovation will increase the concentrations of CO_2 emissions in Malaysia.

H_2: **H_0: Economic growth in Malaysia will deteriorate the environmental quality**

H_A: Economic growth in Malaysia will improve the environmental quality

H_3: **H_0: EKC relationship between higher per capita income and CO_2 emissions is validated in Malaysia**

H_A: EKC relationship between higher per capita income and CO_2 emissions is not validated in Malaysia

3.6.2 Model 2: The Impact of Structural Changes in the Economy on the Environmental Quality

The nexus between economic growth, energy consumption and CO_2 emissions has been the center stage of theoretical and empirical studies in the recent past (Alkhathlan et al., 2012a; El et al., 2012; Heidari et al., 2015; Ozcan, 2013; Saboori et al., 2012; Saidi & Hammami, 2015). Furthermore, some researchers argued that structural changes can affect the environmental quality as an economy moves from agriculture based to the more industry based economy. The current study includes the structural change in the model because Malaysia is one of the developing countries which is in the state of transition and has moved from the former agriculture based economy to a mode industrial economy and is on the verge to meet the developed nations of the world. Structural changes in the economy are thought to affect the environmental quality (D. Bruyn & Sander, 1997; Hidalgo & Robinson, 1996; Luukkanen et al., 2015; Maréchal, 2007; Marsiglio, Ansuategi, & Gallastegui, 2016; Pasche, 2002; Ramer, 2011).

It is argued that there is strong link between structural change hypothesis and "Kuznets facts", as it proposes that changes in the economic production function is due to the structural changes in an economy as a result of shift from agriculture (low polluting) to industries (high polluting) and ultimately again to services sector economy (low polluting (Panayotou, 1993). There has been some empirical work done to investigate the impact of structural changes in the economy on the income-pollution pattern. The current study is also an effort to analyze the impact of structural change on the environmental quality (income-pollution relationship) under the umbrella of EKC.

Following the work of (Marsiglio et al., 2016) we can rewrite the carbon emissions intensity from a country as:

$$I = \frac{C}{Y} = \frac{\Sigma_{i,j} C_{ij}}{Y} = \sum \frac{C_{ij}}{E_{ij}} \frac{E_{ij}}{E_i} \frac{E_i}{Y_i} \frac{Y_i}{Y} = \sum f_{ij} m_{ij} e_i s_i \qquad (3.10)$$

Where carbon emissions is represented by fij for j energy source and i sector, the share of energy source j in sector i is represented by m_{ij}. The intensity of energy is of sector i represented by e_i, and the shared of gross value added in aggregate in sector i s_i. Differentiating both sides of Eq. (3.10) with respect to time, we have:

$$\dot{I} = \sum m_{ij}\, e_i s_i \dot{f}_{ij} + \sum f_{ij} e_i s_i\, \dot{m}_{ij} + \sum f_{ij}\, m_{ij} s_i \dot{e}_i + \sum f_{ij}\, m_{ij} e_i \dot{s}_i \qquad (3.11)$$

An observed change Eq. (3.11) shows an observed change in the intensity of carbon emissions (i). Carbon emissions intensity can be decomposed into four effects; (i) the effect of changes in the carbon emissions coefficients, (ii) the effect of changes in the sources of energy, (iii) the effect of changes in the intensity of energy, and (iv) the effect of changes in the structure of economy.

It is known that the final consumption good, y_t, in a competitive sector is produced under the Cobb-Douglas production function as follows:

$$y_t = a(u_t x_t)^{\alpha} k_t^{1-\alpha} \quad (3.12)$$

By combining the manufacturing capital k_t, and production of goods under the share of services sector, $u_t x_t$, services sector is denoted by x_t, and $u_t \epsilon [0, 1]$. The shares of services and manufacturing sectors are represented by α and $1 - \alpha$.

Where α is a scale measuring the total factor productivity (TFP) and is nonlinearly dependent upon the ratio of services and manufacturing sectors shares of capital stock, $\frac{k_t}{x_t}$, as follows:

$$\alpha = (k\_t / x\_t\ )^{\emptyset} \quad (3.13)$$

where $\emptyset \in \mathbb{R}$ is used to measure the intensity of production externality which affect the final goods. When $\emptyset > 0$ the social returns are less (higher) than the privately perceived returns to services (manufacturing) capital. On the other hand, when $\emptyset < 0$ the social returns are higher (lower) than privately supposed returns to services (manufacturing) capital.

It is argued that some pollution, z_t in the form of negative externality is generated while production occurs as follows:

$$z_t = \eta k_t^{\psi(1-\alpha)} \quad (3.14)$$

where η, ψ are parameters that measure the degree of efficiency of environmental quality. Since there is no concept of internalization of production environmental externalities in firms, thus, the instantaneous profit's maximization leads to:

$$r_t = a\alpha \left(\frac{k_t}{u_t x_t}\right)^{1-\alpha} \quad (3.15)$$

$$\rho_t = a(1-\alpha)\left(\frac{k_t}{u_t x_t}\right)^{-\alpha} \qquad (3.16)$$

where the production of final goods leads to the marginal productivity functions of manufacturing and services sectors which are represented by r_t and ρ_t respectively. Thus, we can say that the process of production and structural change (manufacturing and services sector activities) are related to environmental pollution. Replacing carbon emissions intensity (I) with CO_2 emissions we can say that in the process of production there will be some CO_2 emissions in the atmosphere. Thus, we can say that:

$$CO_2 = f(Y, Structural\ change) \qquad (3.17)$$

where Y is the production output and structural change represent the shares of services and manufacturing sectors to total GDP in the shape of industry value added. Thus, we can write Eq. (3.17) as following:

$$CO2 = f(Y, INVAD) \qquad (3.18)$$

The current study measures the structural change in the shape of industrial value added (INVAD) which is a proxy used for structural change in the previous literature, including McMillan & Rodrick (2011), Suri & Chapman (1998), and Luukkanen *et al*. (2015) among others. The current model is unique as no other study until now has covered the structural change, in the shape of industrial value added (INVAD), and CO_2 emissions relationship in the case of Malaysia. Moreover, it is argued that trade openness is the one of the main drivers of structural changes in the economy, thus the study included the trade openness in the model in order to cover the omitted variable bias as international trade is considered important for the structural change in the economy (Ben-David & Papell, 1997; D. Bruyn & Sander, 1997; Dupuy, 2015; Teignier, 2012). Similarly, trade also can affect CO_2 emissions (Antweiler, Copeland, & Taylor, 2001; Copeland & Taylor, 2004; Farhani et al., 2014). Thus, our model took the shape:

$$CO2 = f(Y, INVAD, Trade) \qquad (3.19)$$

$$Or\ CO2 = f(GDP, K, INVAD, Trade) \qquad (3.20)$$

Where GDP is used to measure the economic growth, K is capital and there are two types of capital, one is polluting and the other is non-polluting. We consider the polluting capital i.e. energy resources which emit CO_2 emissions, thus we can replace it by EC. Structural changes in the economy are represented by industry value-added. Trade is used to measure the impact of trade openness on the quality of environment. The current model is unique as no other study until now has covered the structural change and CO_2 emissions relationship in the case of Malaysia. The study included the squared term of GDP to test the environmental Kuznets curve hypothesis between income and pollution in the case of Malaysia in the presence of structural change.

Following the literature, the CO_2 emission function is as follows:

$$CO_2 = f(GDP, GDP^2, EC, INVAD, Trade\,) \qquad (3.21)$$

Where CO_2 emissions are shown as a function of GDP, the square term of GDP, energy consumption, structural change (services sector activities, manufacturing activities) in the form of industry value-added and trade openness. The current model in the study covers a period 1971 to 2013 because the data on variables in the case of Malaysia is available from 1970 onwards. The conversion of this function into econometric model is as follows:

$$CO_2 = \beta_0 + \beta_1 EC + \beta_2 GDP_{pc} + \beta_3 GDP^2 + \beta_4 INVAD + \beta_5 Trade + \epsilon \qquad (3.22)$$

Where ϵ represent the error term in the model. The variables are converted into the logarithmic form as to avoid the problem of heteroscedasticity and the equation can be written as:

$$lnCO_{2t} = \beta_0 + \beta_1 lnEC_t + \beta_2 lnGDP_t + \beta_3 \ln(GDP_t)^2 + \beta_4 lnINVAD + \beta_5 lnTrade_t + \epsilon_t \qquad (3.23)$$

Based on the literature the hypotheses of this model are as follows:

H_4: H_0: Structural changes in the economy will improve the environmental quality in Malaysia

H_A: Structural changes in the economy will deteriorate the environmental quality in Malaysia

H_5: H_0: EKC relationship between higher per capita income and CO_2 emissions is validated in Malaysia

H_A: EKC relationship between higher per capita income and CO_2 emissions is not validated in Malaysia

H_6: H_0: Trade openness will deteriorate environmental quality in Malaysia

H_A: Trade openness in Malaysia will improve environmental quality

3.6.3 Model 3: The Role of Interest Rate in the Environmental Perspective

Climate change and global warming are a long-term phenomenon and the policies and strategies formulated to tackle these challenges are based on the long-term goals. To preserve the ecosystem services and climate, the long-term policies need discount rates to evaluate the problem accordingly. It is argued that since the long-term climate change mitigation's potential efficiency is dependent on abatement costs and benefits, so the dependence on the discount schemes is very important (Sjølie *et al*., 2013; Stern, 2006). Some studies support declining discount rates while others are in favor of increasing or constant discount rates (Groom *et al*., 2007; Guo, Hepburn, Tol, & Anthoff, 2006; Kögel, 2009; Rabl, 1996; Tsur & Zemel, 2009; Williams & Goulder, 2012). Furthermore, some studies argued to apply dual discounting rates to mitigate the climate changes (Kula & Evans, 2011; Sjølie *et al*., 2013; R. S. J. Tol, 2004; Weikard & Zhu, 2005; Z. Yang, 2003). Some other researchers support the use of interest rate as the discount rate to mitigate the long-run GHG emissions (Di Vita, 2008a, 2008b; Rashid & Sharma, 2008). The current study focused on the use of interest rates, as real interest rates can influence the environmental quality in two ways. One way is that interest rate affects the polluting capital, which in turn pollute the environment (Rashid & Sharma, 2008). The second source of influence of interest rate is that if the interest rate will decrease (increase), the capital-intensive firms will comparatively invest (save) more relative to the labor-intensive firms (Rashid & Sharma, 2008).

On the other hand, it is argued that when the per capita income of people will be low, there will be a high interest rate (marginal rate of return on capital)[9], as to satisfy their needs individuals will invest in capital accumulation regardless of the negative externalities in the shape of environmental pollution in their utility function. When the country become wealthier the interest rate (marginal return on capital) will decrease and there will be more willingness in the agents to invest their saving in pollution abatement technologies. This phenomenon is also due to the decrease in the 'impatience' when the people become richer (Chavas, 2004). This delay option in the environment-friendly measure until the decrease in the rate of interest can be justified theoretically as a decrease in the interest rate alone is enough to explain the positive and negative relationship between income and pollution as income grows. Following the work of Ramsey (1928) and the theoretical framework of Cass (1965) and Koopmans (1965) (the RCK model) we can explain the role of a decreasing interest rate in the income pollution mechanism as the income increases by keeping the interest rate as an endogenous variable (Di Vita, 2008b).

Following the work of (Di Vita, 2008a) we start the model from technology. It is argued that final output Y is the combination of labor effort (v) and capita (K) in the economy. Thus, the production function can be written as:

$$Y = K^{\alpha_1} v^{\alpha_2}, \qquad with\ \alpha_1 + \alpha_2 = 1 \tag{3.24}$$

which satisfy the so-called Inada conditions. Assuming the labor force (L) in the country equal to one, the number of workers that are involved in pollution abatement can be represented by $(1 - v)$. In a closed economy, individuals will save the amount of product that is not utilized for the purpose of consumption or investment, thus the law of motion of physical capital is

$$K = Y - C,\ where\ K = 0\ K_0\ and\ K(t)\ \geq\ 0. \tag{3.25}$$

Which is a constraint to show change in K over time. The aggregate consumption $C = xY, with\ 0 < x \leq 1$.

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[9] Interest rate in the steady state should be equal to the marginal rate of return of capital (Di Vita, 2008a)

Since the process of production and consumption involve the emissions of some pollutants $E = Y^{\gamma}\ , with\ 0 < \gamma \leq 1$ which indicate the rate of increase or decrease of emissions. E is used as a control variable to direct the changing aspects of stock of pollution (M) over time, if there are no pollution abatement policies involved. If there are pollution abatement policies involved, M depends upon the efforts of labor to abate the amount of pollution (Ea). Thus, the transition equation of the stock of pollution is:

$$\dot{M} = \sigma E - Ea - \pi M \qquad (3.26)$$

According to the work of Andreoni & Levinson (2001) Ea is having inverse relationship with the amount of pollution, i.e. greater the amount of pollution, lower will be the average and marginal cost of abatement. Moreover, it is argued that utility is dependent upon the per capita consumption, thus households can decide the utility function regarding the consumption and savings.

$$u = u(C, M) = \frac{C^{1-\theta}}{1-\theta} - \frac{M^{1+\omega}}{1+\omega}, \text{ with } \theta, \gamma = 0 \qquad (3.27)$$

Where θ represents the elasticity of marginal utility of consumption and ω represents the elasticity of marginal utility stock of pollution. The utility function involves the stock of pollution as it can have only negative effect on the welfare (Keeler et al., 1972).

The utility function is facilitated with the inclusion of an exogenous social discount rate $\delta > 0$. Thus, the total welfare W is calculate as:

$$W = \int_0^x u(C, M) e^{-\delta_t}\, dt; \qquad (3.28)$$

this equation represents that the present or future welfare and resources are considered by the present generation. Maximizing Eq. (3.28) subject to (3.24)–(3.27), we arrive at a proper Hamiltonian for the problem as:

$$H = \left(\frac{C^{1-\theta}-1}{1-\theta} - \frac{M^{1+\theta}+1}{1+\theta}\right) e^{\delta t} + \lambda_1 (K^{\alpha_1} v^{\alpha_2} - C) - \lambda_2 \{(K^{\alpha_1} v^{\alpha_2})^{\gamma} \left[\sigma\left(1 - v\right)^{\beta_2}\right] - \pi M \qquad (3.29)$$

where the current values of the shadow prices of capital and stock of pollution are represented by $\lambda_i = 1{,}2$. Since pollution creates negative externality and is considered to reduce the welfare, thus, $\lambda_2 < 0$.

To calculate the motion equation of consumption the study applied first-order condition of partial derivatives, calculated the values of λ_1 and λ_2 and the growth rates of dynamic multipliers after eliminating the value of λ_2 and a little algebra (see for details Di Vita, 2008a). The motion equation of consumption is as:

$$C = \frac{C}{u''(C)C/u'(C)}\left\{\delta - r\left[\frac{\alpha_2\gamma^{\sigma}(1-v) - (1-v)^{\beta_2}(\beta_2 v - \alpha_2\gamma}{(1-v)^{\beta_2}v(\beta_2 - \alpha_2\gamma}\right]\right\} \tag{3.30}$$

where rate of interest is represented by $r = \alpha_1 Y/K$.

According to Di Vita (2008a) $u''(C)C/u'\,(C) = -\theta$ and letting $\alpha_2\gamma_{\sigma}\,(1-v) - (1-v)\beta_2\,(\alpha_2\gamma - \beta_2 v)/(1-v)\beta_2\,v\,(\beta_2 - \alpha_2\gamma) = \varphi$ (where $\varphi > 0$). Thus, we can rewrite Eq. (3.30) as:

$$\dot{C} = \frac{C}{\theta} - \{r\varphi - \delta\} \tag{3.31}$$

Thus, we should find the equation that describe r to study the relationship between stock of pollution and interest rate. We can obtain r by means of Eq. (3.32) (see for details Di Vita, 2008a).

$$r = \frac{C}{\theta}\{r_{\varphi} - \delta\} \tag{3.32}$$

where the internalization impact of the negative externality of environment i.e. pollution, on the interest rate is represented by $1/\varphi > 0$.

Incorporating the evidence in Eq. (3.32) that $\sigma - (1-v)^{\beta_2}$ and substituting in Eq. (3.28) we can link the dynamics of interest rate with the pollution as:

$$\dot{M} = (K^{\alpha_1}v^{\alpha_2})^{\gamma}\left(\frac{r - \theta g_c - \delta}{r\alpha_2\gamma}\right)\left\{\alpha_2\gamma\left[\sigma - (1-v)^{\beta_2 - 1}\right] + (1-v)^{\beta_2 - 1}\beta_2 v\right\} - \pi M \tag{3.33}$$

where M is the direct function of interest rate, and we can say that the absolute change in the stock of pollution will be greater if the interest rate is higher and vice versa.

Looking at the above relationship between interest rate (r) and pollution (M) in Eq. (3.33), in the presence of capital (K), labor efforts (v) and the resulting production (Y), we can replace the stock of pollution M by CO_2 emissions. Similarly, we know that there are two type of capital, one is the polluting capital and the other is the non-polluting capital i.e. $K = K_e + K_0$, thus we can replace the capital K by polluting capital i.e. energy resource, thus energy consumption, as only this part is involved in the emissions. The output (Y) in the equation can be replaced by per capita income (GDP) as production activities leads to emissions. The study further emphasized on the inclusion of the squared term of GDP to look for the EKC relationship between income and pollution in the presence of interest rate. Thus, we can relate the interest rate and pollution in the following way:

$$CO_2 = f(Ec, GDP, GDP^2, RIR) \qquad (3.34)$$

where CO_2 emissions is a function of energy consumption, per capita income, squared term of per capita income (EKC), and real interest rate. Taking logarithms of the variables, we can rewrite the above function in the econometric form as follows;

$$lnCO_{2t} = \beta_0 + \beta_1 lnEC_t + \beta_2 lnGDP_t + \beta_3 ln(GDP_t)^2 + \beta_4 RIR_t + \epsilon_t \qquad (3.35)$$

Where ϵ represent the error term, RIR is the real interest rate, EC represents the polluting capital in the economy, GDP is the economic growth, the squared term is included to look for the validation of EKC in the model. This model is the first of its type in the environmental scenario in Malaysia and somewhat all over the world. The period for this model is from 1987 to 2013, as the data on real interest rate is available from 1987 onwards.

H_7: **H_0: Low interest rate can be helpful in improving the quality of environment**

H_A: High interest rate can be helpful in improving the quality of environment

H_8: H_0: EKC relationship between higher per capita income and CO_2 emissions is validated in Malaysia

H_A: EKC relationship between higher per capita income and CO_2 emissions is validated in Malaysia

3.7 Methodology to Achieve the Objectives

3.7.1 Unit Root Tests

Since macroeconomic data is more often time series in nature and two important methods namely the stationarity method and method of cointegration are adopted to validate the data for statistical analysis. When the data are time series in nature, the regression analysis becomes more complex because of the assumption that there will be a long-run effect of the regressors on the regressand. Since the data in the current study are time series, therefore, to investigate and analyze the relationship between the study variables, the present study adopted the standard econometric procedures. Since the present study is analyzing the time-series secondary data, so the proper way to regress the data is to check the properties of the data set. It is argued that most of the time-series data is in a non-stationary, i.e. there is a trend present in the data and per the rules of regression, the data must be stationary while performing regression. The stationarity of a series is based upon its mean and autocovariance, if the mean and autocovariance of a series are not dependent on the time it is called a stationary time series. Stationarity is very important for the regression analysis of time-series, and it can be achieved when the probability distributions of time series are stable over time such as if there occur a shift in time by say h times, there should be no changes in the probability distribution. The Random walk is the most common example of a non-stationary series (Wooldridge, 2013).

$$y_t = y_{t-1} + \varepsilon_t \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.36)$$

Where ε represent the stationary random disturbance term. In this series, there occur an increase in the variance over time and the series y has a constant forecast value dependent upon t. The first difference of y is stationary; therefore, this random walk series is called a difference stationary series:

$$y_t - y_{t-1} = (1 - L)y_t = \varepsilon_t \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (3.37)$$

In a differenced stationary series with an order of integration d the series is said to be integrated and is denoted by I (d). The number of unit roots in the series, or the differencing operations to make the series stationary represent the order of integration. A series is stationary at, I (1) if there is only one unit root in the series. The above random walk series is also stationary at first difference having one unit-root, so it is integrated of order, I (1). It is argued that the regressions with integrated independent variables or dependent variable do not fit for the application of standard inference procedures. Therefore, the stationarity order of the series is very important to be known before running a regression. The unit root tests are applied conventionally to detect the stationarity in a series. There are some popular unit root tests, including Augmented Dickey-Fuller (ADF) (1981), Phillips-Perron (PP) (1988), Dickey-Fuller GLS (DF-GLS) (1996), Kwiatkowski-Philips Schmidt Shin (KPSS) (1991), Elliot-Rothenberg-Stock-Point-Optimal (ELS) (1996), and NG-Perron (2001). All these tests can detect the unit root in the data and is used alternatively in different cases. The most commonly used tests of stationarity are Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. Along with these two, the most common test the current study also emphasized on the Dickey-Fuller GLS (DF-GLS) and NG-Perron unit root tests to identify if there is any unit root in the data set of the study.

3.7.1.1 Augmented Dickey-Fuller (ADF) Unit Root Test

The Augmented Dickey-Fuller (ADF) unit root test introduced by Dickey and Fuller in 1981 is a unit root test to check the stationary properties of a given time series. The basic autoregressive unit root test was augmented by (Said & Dickey, 1984) in order to accommodate general ARMA (p, q) models having unknown orders and the test is known as the augmented Dickey-Fuller (ADF) test. The null hypothesis if the ADF test is that a time series is integrated of order, I (1) and the alternative hypothesis is that the series is integrated of order, I (0). They assume that the data is having the dynamics of an ARMA structure. Augmented Dickey-Fuller (ADF) model in its regression form, with random walk, drift and deterministic trend (3.30), with random walk and constant drift (3.31) and random walk with no trend and a constant drift (3.32) are as follows:

$$\Delta Y_t = \alpha + \beta t + \delta y_{t-1} + \sum_{i=1}^{p} \gamma i \Delta y_{t-i} + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.38)$$

$$\Delta y_t = \alpha + \delta_{t-1} + \sum_{i=1}^{p} \gamma i \Delta y_{t-i} + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.39)$$

$$\Delta y_t = \delta_{t-1} + \sum_{i=1}^{p} \gamma i \Delta y_{t-i} + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.40)$$

Where Yt represents the variable of interest, the time index is represented by t, the constant intercept value is represented by α, the coefficient on a time trend by β, the process root is presented by δ, and εt represent the residual term which is identically and independently distributed(iid).

3.7.1.2 Phillips-Perron (PP) Unit Root Test

Phillips & Perron (1988) proposed a new and alternative (nonparametric) unit root test, which controls for the effect of serial correlation (i.e. it ignores the serial correlation and heteroscedasticity). The PP test modifies the coefficient ratio and estimates the non-augmented DF test so that the asymptotic distributions of the test statistics are not affected due to the serial correlation. The PP model with a constant and the trend can be presented as follows:

$$y_t = \alpha + \beta_t + \delta y_{t-1} + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.41)$$

Where α represent the constant drift, the coefficient of a time trend is represented by β, δ indicates the process root, and the independent and identically distributed error term is represented by ε. This test is different from the ADF in the aspect of neglecting the serial correlation and heteroscedasticity and correcting for it by applying the Newey-West corrections of standard deviations (non-parametrically). The PP test is considered as superior to ADF test because of the robustness of the PP test in the error term for the common forms of heteroscedasticity. The PP test has also the advantage of no manual specification of the lag length to run the regression. The PP test has the disadvantage of working well only in case of large sample size and not suitable for small samples as it is based on the asymptotic theory.

3.7.1.3 Dickey-Fuller GLS (DF-GLS) Unit Root Test

After the common use of ADF and PP unit root test and considering their weaknesses, Elliott, Rothenberg and Stock (ERS) modified the test statistics of Dickey-Fuller test by introducing a generalized least square (GLS) rationale and proposed a new unit root test called the DF-GLS. According to them, this new modified test is superior to the ordinary Dickey-Fuller test as it dominates the ADF in overall performance looking at the power and small sample size. It is argued that the DF-GLS test "has substantially improved power when an unknown mean or trend is present" (Elliott, Rothenberg, & Stock, 1996). The DF-GLS test can be run similarly as that of the Dickey-Fuller test with or without any trend. The ERS is used to measure the critical values of GLS detrending and the DF-GLS routine provides the interpolated values. The interpolated values for GLS demeaning is provided by DF-GLS and the Dickey-Fuller critical values with no trend and no constant are used for GLS demeaning.

3.7.1.4 NG-Perron (NP) Unit Root Test

The problems of ADF and PP unit root test that are the too small size of lags when there is a large autoregressive (AR) root (DeJong, Nankervis, Savin, & Whiteman, 1992), and has a low power against the large negative moving average (MA) (Ng & Perron, 2001; Schwert, 1989). These problems lead the econometricians like Ng Serena and Pierre Perron to introduce such a test that can overcome both these problems of size and power. Ng & Perron (2001) building on their own work and also looking into the work of Elliott *et al*. (1996) introduced new tests in order to cope with both the problems of size and power. The NP test first applies the GLS estimator to the time series to demean or detrend. This step in the NP test is used to improve the power of tests against the large autoregressive (AR) roots and the size of the alterations or misinterpretation due to large moving averages (MA) is reduced in the differenced series. Secondly, the NP tests apply the modified lag selection criteria. It is argued that the lag length selection criterion used in ADF or the procedures to calculate the long-run variance for the PP statistics tends to underfit the size of the lags to be selected in the presence of a large MA root which leads to an additional misinterpretation of the unit root tests due to the selection of too small lag length. This discrepancy is covered by the NP modified lag selection criteria. It is argued that the power of the test can be improved by applying the GLS detrending procedure. It is argued that PP test suffers from the poor size properties, the Z test proposed by PP was modified by NP in order to overcome the problem of poor size. It is argued that in theory with M tests the size misrepresentations are not a big issue (Ng & Perron, 2001). On the other hand, in practice, the use of appropriate k is very necessary. In the absence of the problem of lag length, the GLS detrending provides an edge to DFGLS over the DF test, so naturally, the M test should be under GLS detrending. The modified Z tests can be written as:

$$MZ_t^{GLS} = MZ_\alpha^{GLS} + MSB^{GLS} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad (3.42)$$

The MZ_t^{GLS}, MZ_α^{GLS} and MSB^{GLS} are collectively called the M^{GLS} tests and all have the same power and size properties. The M^{GLS} is more powerful than the M tests under OLS and is also having the indistinguishable local asymptotic power functions from DF^{GLS} and is also according to the Gausian asymptotic power function.

3.7.2 Model Slection Criteria

One of the important steps in the regression analysis is to select the model on the basis of some a priori defined criteria. There are several criteria in statistics including Akaike information criterion (AIC), Schwarz Information Criterion (SIC), Hannan-Quinn Criterion (HQ), Log Likelihood, R^2, Adjusted R^2, Durbin-Watson (DW) statistics, and forecast χ^2(Chi-square), etc. The most commonly used criteria of all these are AIC, SIC and R^2 and the current study focused on the AIC and SIC criteria to select the model.

3.7.2.1 Akaike Information Criterion (AIC)

The model selection criteria impose a penalty when an extra variable is added to the model. This restriction or penalty is imposed in the shape of AIC, which is addressed as follows:

$$AIC = e^{\frac{2k}{n}} \sum \grave{u}_i^2 / n = e^{\frac{2k}{n}} RSS/n \tag{3.43}$$

Where the number of independent variables is represented by *k* and n represent the number of observations. Taking logs of both sides the (3.27) can be written as:

$$lnAIC = \left(\frac{2k}{n}\right) + \ln\left(\frac{RSS}{n}\right) \tag{3.44}$$

Where 2k/n is the factor of penalty and *ln*AIC = AIC natural log.

It is argued that AIC is preferred over Adjusted R^2 because the AIC criterion put a bit harsher penalty on the inclusion of extra variables. The model with the lower AIC value is selected over the one with a higher AIC value when we have to compare two or more models. The advantage of AIC criterion is that it is useful in the forecasting the performance of in-sample as well as out of the sample regression model. The AIC criterion is applicable to both nested and non-nested models and can also be employed to AR (*p*) model to determine the number of lags (Gujarati, 2004).

3.7.2.2 Schwarz Information Criterion (SIC)

Another information criterion almost similar in spirit to that of AIC is the SIC and is described as:

$$SIC = n^{\frac{k}{n}} \sum \hat{u}^2 / n = n^{\frac{k}{n}} \frac{RSS}{n} \tag{3.45}$$

Or the log form is as:

$$lnSIC = \frac{k}{n} \ln n + \ln\left(\frac{RSS}{n}\right) \tag{3.46}$$

In this criterion, the penalty factor is represented by [(k/n) *ln* n] which is comparatively harsher than that of AIC criterion. The model is selected on the basis of the lower value of the SIC of different models. Furthermore, similar to AIC the SIC also has the ability to compare the forecasting performance of the model based on in-sample and out-of-sample properties (Gujarati, 2004).

3.7.3 Tests of Cointegration

Granger (1987) while preparing a phenomenon to find out the stationary linear combination of the nonstationary process coined the term cointegration. The time series is said to be cointegrated if there is long-run systematic co-movement among the series. It is argued that a series can be named as cointegrated if there is a stationary linear relationship between the non-stationary series. The test of cointegration is important to provide meaningful and robust results of a regression process. It was Engle & Granger (1987) who analyzed a set of, I (1) variables in order to test the problem the null hypothesis of no cointegration. The coefficients of a static relationship between these variables were estimated applying the ordinary least squares method and employed the well-known unit root test to check for the properties of residuals. The study concluded that the rejection of unit root could be an evidence to look for cointegration. The two-stage estimation method for VAR models having cointegration was developed by Engle & Granger (1987). This two-step method for VAR estimation embodied a significant revolution to the modeling of economic relationships, concentrating on the non-stationary time series.

Another most popular test of cointegration is the VAR-based cointegration test introduced by Johansen (1992a). The Johansen test of cointegration is superior to the other test of cointegration like Engle and Granger because they allowed only for a cointegrating relationship, but there can be more relationships under the Johansen test of cointegration and thus is more applicable to the analysis of time series. A general VAR (p) model can be written as:

$$y_t = \alpha_0 + \sum_{j=1}^{p} A_j \, y_{t-j} + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.47)$$

Where y_t is the variable of interest, α_0 is the vector of constant terms in equation, A_j represents the matrix of VAR parameters for j lags, and ε_t is the vector of the error term. It is important to consider the inclusion of deterministic components of the equation like a constant, trend, both or no one, for the correct specification of the equation in the Johansen test of cointegration. The Pantula principle developed by Pantula (1989) is suggested by Johansen, (1992b) in order to estimate the model. According to this method, three models will be estimated, starting from the most restrictive model with no trend and only restricted constant, to the least restricted model having unrestricted trends and unrestricted constant and compare its critical values at each stage with trace statistics. The test concludes and complete when the null hypothesis of cointegration is accepted.

The Johansen test of cointegration can be considered as the general form of augmented Dickey- Fuller test in a multivariate framework. The linear combination between the unit roots is observed by generalizing the ADF. The edge of the Johansen test of cointegration is that it can estimate if there are more than one cointegrating vectors in the model, and the maximum likelihood strategy of estimation is the base for it. It is argued that there will be two cointegrating vectors if there are three non-stationary variables having unit roots (i.e. for n variables, there will be n-1 cointegrating vectors). Furthermore, if the number of cointegrating vectors is equal to the number of variables, it is argued that these variables will not have unit roots because each variable alone as a scalar multiple of itself only represent the cointegrating vectors, thus they are not unit root variables (Dwyer, 2014). The Johansen tests are a maximum eigenvalue and trace statistics tests. Let the rank of π be represented by r, both tests of cointegration test for the null hypothesis of no cointegration. These tests differ on the basis of the alternative hypothesis.

3.7.3.1 The Maximum Eigenvalue Test

The Johansen test of cointegration for the maximum eigenvalue studies the null hypothesis that the largest eigenvalue is zero relative to the alternative that the next maximum eigenvalue is zero. In the first test, it is considered that π is zero, which is the rank of the matrix. Here in this test, the null hypothesis is that the rank (π) =0, against the alternative hypothesis that the rank (π) =1. For the higher order and further tests, the test considered that the null hypothesis of rank (π) =1, 2… and the rank (π) =2, 3... It is considered that largest eigenvalue will be zero if the rank of a matrix is equal to zero, there is no cointegration and the tests are done. On the other hand, there will be more cointegrating vectors if the rank of the eigenvalue is at least 1 and the largest value of λ1 is nonzero. Similarly, if the second largest eigenvalue λ2 is zero, there will be exactly one cointegrating vector, and there will be more cointegrating vectors if this second eigenvalue is not zero.

3.7.3.2 The Trace Statistics Test

Another test that Johansen introduced in order to check for the cointegrating vectors is the trace statistics test. This test is used to check whether the null hypothesis is accepted or rejected which is the rank of the matrix $(\pi) = r_0$ against the alternative hypothesis that $r_0 < \text{rank}\ (\pi) \leq n,$ where the number of possible vectors of cointegration are represented by n. If the null hypothesis is rejected for the succeeding test, the null hypothesis for the next test will be ranked $(\pi) = r_0$ +1 and the alternative hypothesis of the second test will be $r_0 + 1 < \text{rank}(\pi) \leq n.$ The testing of the hypothesis is same as that of the maximum eigenvalue test. This test is called the trace test because the trace of matrix is based on the standard Wiener Process or Brownian motion in the test statistics asymptotic distribution (Johansen, 1995). The current study applied Johansen tests of cointegration in order to find out the number of cointegrating vectors in case when all the variable in a model are integrated of order I (1) i.e. stationary at first differences.

3.7.4 Autoregressive Distributed Lagged (ARDL) Model

To estimate the efficient long-run relationship there are several cointegrating techniques introduced until now. To derive the efficient estimators with a mixture of normal distributions, (Park & Simar, 1994; P. . C. Phillips & Hansen, 1990) introduced semiparametric approaches. Similarly, the augmented regression with leads and lags of the first difference regressors were applied by Stock & Watson, (1993); Phillips & Loretan (1991); and Saikkonen (1991) to derive the similar efficient estimators as a semiparametric approach. This approach is called the dynamic OLS regression or the leads-and-lags regression. Choi & Saikkonen (2004) used this approach to derive at a smooth transition regression. Furthermore, assuming the normal distribution of residuals the vector autoregressive (VAR) technique was introduced by (Johansen, 1988) in order to derive the maximum likelihood estimator of the cointegration. Last but not the least, an autoregressive distributed modeling approach was used by Pesaran, Shin, & Smith (1999) to address the interpretation of cointegrating vectors. The autoregressive distributed lagged (ARDL) modeling was introduced by Pesaran *et al*. (2001), which is the most recent and dominant of all these discussed approaches to cointegration. The application of the ARDL approach to cointegration can be widely found in the empirical literature due to its supremacy over the other techniques of cointegration including the Johansen & Juselius (1990) technique known as the standard Johansen Cointegration technique. The ARDL approach is superior to the Johansen cointegration technique due to its more desirable properties for cointegration. First, the ARDL approach is better than the Johansen cointegration technique due to its better small sample (Ghatak & Siddiki, 2001; Narayan, 2005). Second, there are no limitations of the order of integration in the ARDL approach as it can estimate the variables having integration of order I(0), I(1) and even a mixture of I(0) and I(1) and it is not possible in the Johansen approach, where all the variables are required to be integrated of order, I(1). Third, there is no danger of the endogeneity problem in the ARDL approach as all the variables are considered as endogenous and it provides the unbiased long-run estimates and has valid t-statistics (Narayan, 2005; Odhiambo, 2009). Fourth, both short and long-run estimates can be derived using the ARDL approach, and this technique of the simultaneous short and long-run results give much of the preference over other tests of cointegration. The ARDL approach statistics are based on the Wald or F-statistics in the regression similar to the ADF type of testing the variable's lagged level significance considering the conditional unrestricted equilibrium correction model (UECM) (Pesaran, Shin, & Smith, 2001). Suppose we have variables like CO_2, EC, GDP, GDP^2, then the ARDL approach in its econometric state can be presented as follows:

$$\Delta lnCO_{2t} = \alpha_0 + \sum_{k=1}^{n} \alpha_1 \Delta\, lnCO_{2(t-k)} + \sum_{k=0}^{n} \alpha_{2k}\, \Delta lnEC_{t-k} + \sum_{k=0}^{n} \alpha_{3k}\, \Delta lnGDP_{t-k} + \sum_{k=0}^{n} \alpha_{4k}\, \Delta lnGDP_{t-k}^{2} + \varphi_1 lnCO_{2(t-1)} + \varphi_2 lnEC_{t-1} + \varphi_3 lnGDP_{t-1} + \varphi_4 lnGDP_{t-1}^{2} + \epsilon_t \quad (3.48)$$

Where α_0 is the drift component in the equation and ϵ_t is the white noise. The error correction dynamics are represented by $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and the long-run relationship is shown by $\varphi_1, \varphi_2, \varphi_3, \varphi_4$.

The first step in estimating the ARDL bounds testing approach is to use the OLS to estimate the above Eq. (3.48). Since Wald statistics or joint F-statistics are the baseline for the bounds test to look for the validation of the no cointegration null hypothesis, i.e. $H_0\colon \varphi_0 = \varphi_1 = \varphi_2 = \varphi_3 = \varphi_4 = 0$ and the alternative hypothesis $H_1\colon \varphi_0 \neq \varphi_1 \neq \varphi_2 \neq \varphi_3 \neq \varphi_4 \neq 0$. The F-statistics critical values for a sample size of 500 and 1000 observations are tabulated by (Pesaran *et al*., 2001). On the other hand Narayan (2005) calculated critical values for small sample sizes. The tabulated critical values for the upper and lower values for different significant levels with and without trends respectively. The test rejects the null hypothesis of no cointegration if the calculated value F-statistics is greater than the upper bound tabulated value. The ARDL model estimates the long-run relationship via AIC or SIC. The test also calculates the error correction model (ECM) after the estimation of long-run. The error correction model can be calculated as follows:

$$\Delta lnCO_{2t} = \alpha_0 + \sum_{k=1}^{n} \alpha_{1k}\, \Delta lnCO_{2(t-k)} + \sum_{k=1}^{n} \alpha_{2k}\, \Delta lnEC_{t-k} + \sum_{k=1}^{n} \alpha_{3k}\, \Delta lnGDP_{t-k} + \sum_{k=1}^{n} \alpha_{4k}\, \Delta lnGDP_{t-k}^{2} + \theta ECT_{t-1} + \epsilon_t \quad (3.49)$$

Where (ECT_{t-1}) is the error correction term and indicates the speed of adjustment towards long-run equilibrium. It is argued that if the sign of the (ECT_{t-1}) is negative and significant the model is thought to be converging towards equilibrium.

According to (Pesaran et al., 2001), the long-run equation can be derived from the short-run model in Eq. (3.49) as per Eq. (3.48), thus, we have:

$$lnCO2 = \gamma_0 + \gamma_1 lnEC_t + \gamma_2 lnGDP_t + \gamma_3 lnGDp^2{}_t + \mu_t \qquad 3.(50)$$

Where $\gamma_0 = \frac{\alpha_0}{1-\sum \alpha_{1i}}, \gamma_1 = \frac{\alpha_{2i}}{1-\sum \alpha_{1i}}, \gamma_2 = \frac{\alpha_{3i}}{1-\sum \alpha_{1i}}, \gamma_3 = \frac{\alpha_{4i}}{1-\sum \alpha_{1i}}$

3.7.5 Model Specification and Diagnostic Tests

One of the least understood but most important parts of regression analysis is the model specification. The correct specification of the model is the basic step for the correct estimation and interpretation of parameters. If the model is misspecified there can arise problems in the correct estimation and interpretation of the results. The model misspecification has two main types, the inclusion of an additional and theoretically irrelevant independent variable, and the second type of misspecification arise when a theoretically relevant independent variable is excluded from the model. It is argued that if there is any irrelevant explanatory variable included in the model the variances of the OLS estimates may face some undesirable effects. Similarly, it is concluded that if the irrelevant variable is correlated with other explanatory variables it may lead to the problem of multicollinearity. On the other hand, if one of the relevant variables is excluded from the model due to non-availability of data, or it is unobservable, it leads to omitted variable bias and it can affect the OLS estimates in a way that the OLS estimates will be biased and inconsistent (Wooldridge, 2013).

There can also be one more specification problem estimating the model, i.e. the functional form of the equation while estimating the relationship between the variables of interest. The problem can arise when a non-linear population relationship between variables is estimated by adopting a linear regression model of sample data. This type of estimation will lead us to be biased and inconsistent estimators of OLS. There can also be cases of mis-specification of equations, which turn into the problem of autocorrelation as in the case of dynamic miss-specification where the lagged values of the dependent variables are omitted. In order to deal with the problems of mis-specification in the models Ramsey's RESET test is applied in the study to indicate if there is any kind of mis-specification.

3.7.5.1 Ramsey's Regression Specification Error Test(RESET)

"*The Ramsey RESET test is a general test that determines the likelihood of an omitted variable or some other specification error by measuring whether the fit of a given equation can be significantly improved by the addition of y^2, y^3, and y^4 terms*" (Studenmund, 2001, pp. 193). The Ramsey regression specification error test (RESET) and $\bar{R}^2$ are the most-used formal tests for model specification[10]. In the Ramsey's RESET test any possibility of omitted variable or any mis-specification in the functional form of the model is proxied by these additional terms like y^2, y^3 and y^4. If the overall fit of the model has improved due to the inclusion of these proxies considering the F-test, then we can say that the model is facing the specification error of some sort. The coefficients of the added proxies will be insignificantly different from zero if there is no specification error, then there would be no use of including these proxies (Studenmund, 2001). The study preferred the Ramsey's RESET test over other test because it is easy to apply, as we are not required to specify the alternative specification of the model. Ramsey's RESET is carried out to detect the following types of specification errors:

- Omitted variable, i.e. if the model did not include relevant variables
- Incorrect functional form, i.e. the transformation of some or all variables in y and X into powers, logs, reciprocals, or some other way
- Correlation between X and ε, due to errors in measurement of X, simultaneity or the presence of serially correlated disturbances and lagged values of y.

[10] J. B. Ramsey, "Tests for Specification Errors in Classical Linear Squares Regression Analysis, "*Journal of the Royal Statistical Society,* 1969, pp. 350-371.

It is argued that if there is any of the above specification errors in the model it will result in the non-zero vector for ε (Ramsey, 1969).

The null and alternative hypothesis of the RESET test are as follows:

$$H_0: \varepsilon \sim N(0, \sigma^2 I)$$

$$H_1: \varepsilon \sim N(\mu, \sigma^2 I)\ \mu \neq 0 \qquad (3.51)$$

Other diagnostic tests to test the validity of the model are:

i. Durbin-Watson *d* statistics
ii. Q-statistics, Correlogram
iii. Serial Correlation Test
iv. Breusch Godfray Heteroscedasticity Test
v. Jarque-Bera Test of Normality

3.7.5.2 Durbin-Watson Test for Serial Correlation

The test developed by Durbin and Watson for the detection of serial correlation in the model is known as the Durbin-Watson d statistics and is described as:

$$d = \sum_{t=2}^{t=n} (\hat{u}_t - \frac{\hat{u}_{t-1})^2}{\sum_{t=1}^{t=n} \hat{u}_t^2} \qquad (3.52)$$

Which represent the ratio of the sum of squared differences in the successive residuals to the RSS. The inclusion of successive differences will make the numerator's number of observations one less than n (i.e. *n*-1) in the *d* statistics. The *d* statistics can be easily measured as it is based on the estimated residuals and it is because of this advantage that along with other summary measures, including R^2, adjusted R^2, F, and t values the Durbin-Watson statistics are also presented. The *d* statistics are very useful for the first order serial correlation. It is argued that the value of *d* statistics will be 2 when there is no first order serial correlation. *"Therefore, as a rule of thumb, if d is found to be 2 in an application, one may assume that there is no first-order autocorrelation, either positive or negative"* (Gujarati, 2004). The *d* statistics is not applicable to the autoregressive regressions as they include different lags of the dependent variable.

Similarly, it is argued that the *d* statistics may not be reliable if the residuals are not NIID[11].

3.7.5.3 Breusch-Pagan Godfray LM Serial Correlation Test

It is argued that time series residuals often serially correlate with their own lags in Ordinary Least Square (OLS) regressions. Here, serial correlation means that (a) OLS lose the properties of an efficient linear estimator, (b) overstated and generally incorrect standard errors in regression, and (c) there are inconsistency and biases in the estimates of OLS. The LM test for serial correlation is an alternative to testing for Q-Statistics of serial correlation. This test is based on the Lagrange multiplier (LM) tests which are an asymptotic class test. The LM test is different from the Durbin-Watson (DW) test in that it is applied to detect the higher order errors of ARMA and is applicable regardless of whether the dependent variable is lagged or not. This test developed by Breusch and Godfrey is more general. Under this test (a) it is allowed to include the lagged values of the dependent variable as regressors, (b) the test can be applied to higher order autoregressive errors like an AR (2), AR (3) and (c) the moving averages of the error term are also allowed to enter the equation such as u_{t-1}, u_{t-2} and so on (Gujarati, 2004). The LM test specifies the null hypothesis of no serial correlation up to a pre-specified number of lags *p*. The alternative hypothesis in this test consist of both AR (*r*) and MA (*q*) error process, hence the alternative is an ARMA (*r, q*) errors and the *p* =max (*r, q*). Thus, this test may be useful against different kinds of autocorrelation structures[12].

The null hypothesis can be tested using the F-statistics value obtained, thus if the value of computed F-statistics exceeds the critical value at any significance level we can reject the null hypothesis of no serial correlation. Moreover, the p-value of the computed F-statistics can be useful and we can reject the null hypothesis if the p-value is too low (i.e. <0.05). Similarly, the null hypothesis can be rejected based on chi-

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[11] Ron C. Mittelhammer, George G. Judge, and Douglas J. Miller, *Econometric Foundations*, Cambridge University Press, New York, 2000, p. 550.
[12] Eviews 9 User Guide II p.183

square value if the computed chi-square value is more than the critical value of chi-square at any significance level we can reject the null hypothesis of no serial correlation.

3.7.5.4 Remedial Measures of Serial Correlation

The problem of serial correlation is very critical because the usual OLS estimates will be severely biased and will lead to misleading results. This problem can be handled by first difference transformation i.e. the variables should be converted to first differences and then run the regression again through origin meaning that there will be no constant term in the equation (Gujarati, 2004). Secondly, the problem of serial correlation can be solved by adopting the Robust Standard Error test of $\hat{\beta}_1$ following the method adopted by (Wooldridge, 1989). This technique of robust standard error is sometime called the heteroscedasticity and autocorrelation consistent, or HAC, standard errors because of its robustness to arbitrary heteroscedasticity. The problem of serial correlation can be handled by taking one lag of the dependent variable and treating it like independent variable in the equation. Furthermore, this problem can be handled by dropping some of the insignificant variables from equation (Gujarati, 2004).

3.7.5.5 Breusch Godfray and White Tests for Heteroscedasticity

When the OLS estimates violates the important assumption of the classical linear regression model, which states that, "*variance of each disturbance term u_i, conditional on the chosen value of the explanatory variables, is some constant number equal to σ^2*", which is the assumption of homoscedasticity, the problem of heteroscedasticity arise in the model. Heteroscedasticity refers to the different spread instead of same spread of all the variances in the model. The null hypothesis of the test is that the conditional variance remains constant through the process and do not change with the inclusions of further regressors. The alternative hypothesis of the test is that the conditional variance is not constant and it increases with the increase in the regressors, it is no more a variance with same spread and it leads to heteroscedasticity.

Another test of heteroscedasticity proposed by White is the "General Test of Heteroscedasticity" unlike the Goldfield-Quandt and BG tests of heteroscedasticity which are based on the assumptions of reordering the variables and assumption of normality respectively, the White's test of heteroscedasticity is very easy to implement as it is free of these assumptions[13]. This test can be a pure test of heteroscedasticity or specification error or both based on the presence and absence of cross-product terms. The White's test null hypothesis of no heteroscedasticity is based on an auxiliary regression in which the residuals squares are regressed over the regressors' cross-products. The White's test statistics Obs*R-squared is computed by multiplying the centered R^2 into the number of observations. The asymptotic distribution as a χ^2 of the White's test statistics in the test regression is observed with the degrees of freedom same as the number of slope coefficients. The LM statistics on the White's test is computed by dividing the ESS from auxiliary regression by $2\hat{\sigma}^4$ and is distributed as a chi-square with the same degrees of freedom to number of slope coefficients[14].

The problem of heteroscedasticity can arise due to data collecting technique if not properly handled. Heteroscedasticity can also be faced due to the presence of outliers in the data set. This problem can also be because of the violation of the assumption of CLRM i.e. the model may be mis-specified. Similarly, the problem of heteroscedasticity can stem from the skewness of the different models in data. Furthermore, Banerjee *et al*. (1986) argued that heteroscedasticity may be the outcome of the (i) incorrect transformation of data, (ii) incorrect functional form of the model. The problem of heteroscedasticity is most common in cross-sectional data (Gujarati, 2004). The current study adopted the BG and White's tests for heteroscedasticity.

3.7.5.6 Remedial Measures of Heteroscedasticity

Since the problem of heteroscedasticity is of no concern with the consistency and unbiasedness properties of the estimators in OLS, it disturbs the asymptotic and

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[13] H. White, "A Heteroscedasticity Consistent Covariance Matrix Estimator and a Direct Test of Heteroscedasticity,'' *Econometrica*, vol. 48, 1980, pp. 817–818

[14] Eviews 9 User Guide II, p.187

efficiency property of the OLS estimates. The usual hypothesis-testing process becomes suspicious in the presence of heteroscedasticity as it disturbs the efficiency. This problem of heteroscedasticity can be solved by adopting some remedial measures, including the Weighted Least Squares (WLS) method and White's Heteroscedasticity-Consistent Variances and Standard Errors. The WLS method is applied when the σ_i^2 is known and when the σ_i^2 is not known the White's Heteroscedasticity-Consistent Variances and Standard Errors method is applied to handle the situation.

3.7.5.7 Jarque-Bera Test for Normality

There are several tests of normality in the literature, including histograms of residuals, normal probability plot (NPP) and Jarque-Bera (JB) test of normality. The current study focused on the JB test of normality. It is a large sample or an asymptotic test based on the OLS residuals. The skewness and kurtosis of the residuals of the data set are computed in the following manner:

$$JB = n[\frac{S^2}{6} + (K-3)^2/24\,] \qquad (3.53)$$

Where the sample size is *n*, S represents the coefficient of skewness, and K is the coefficient of kurtosis. A normally distribute variable has S=0 and K=3, so the JB normality test check the joint hypothesis where S=0 and K=3, where the expected value of the JB statistics is 0. The null hypothesis of the JB test shows that the residuals are normally distributed, and the asymptotic JB statistics follow the chi-square distribution with 2 df given in Eq. (3.45). The null hypothesis of normally distributed data can be rejected based on a very different value from 0. However, if the *p*-value is high, as the JB statistics value is close to zero, we cannot reject the null hypothesis of normally distribute data (Gujarati, 2004).

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

Data analysis is a compulsory part of any research to accomplish the desired already set objectives. The analysis of data requires some statistical or econometric techniques to achieve a set of objectives. The current study analyzed the annual time series data for a period 1971 to 2013 to investigate the role of structural changes in the economy in the environmental perspective. The study further analyzed the impact of technological innovation on the environmental quality over a period 1985 to 2013 due to maximum data availability on technological innovation. Moreover, the study employed a dataset over a period 1987-2013 to investigate the role of real interest rate in the environmental perspective. The study followed the basic statistical approach for data analysis and conducted the unit root tests to confirm the stationarity level of the variables. The study then used the ARDL approach, as the variables are stationary at level and first differences. The details of how the objectives of the study are achieved are given below.

4.2 Objective One of the Study: To investigate the impact of technological innovation on the environmental pollution (CO2)

The theoretical background of the technological change can be traced back to the philosophies of Josef Schumpeter (1942) as cited by (Fields, 2004), where he designated that a new and superior technology enters the market in three stages namely invention, innovation, and diffusion. He argued that the process of “research and development” (R&D) is used to carry out the invention and innovation process of technology. Finally, the process of diffusion is carried out when a successful innovation is adopted by individuals and firms for its relevant use and is widely available for the use in relevant applications. The collective impact of all the three, either economic or environmental is known as the process of technological change. The New growth Theory is often known as “endogenous” growth theory due to the internalization of technology as a variable into a model of how market function. It is stated that technical change has a critical importance in describing the key environmental issues, mainly the long-term and large-scale environmental problems, including climate change (IPCC, 1995; Weitzman, 1997). It is argued that there may be a variety of reasons due to which we can understand the importance of technological changes in the reduction of environmental pollution. These reasons include changes in the fuel mix; utilization of production technologies that are more energy efficient; and the installation of end-of-pipe technology which is considered as the most important of all the three (D. Bruyn & Sander, 1997). It is argued that investments in R&D and change in technology are among other sources that can lead to reductions in the carbon dioxide emissions (Jones, 2002). It is contended that if the costs are acceptable to society, in the long-run, the future development of the technology is considered to decrease the intensity of the emissions from economic activities and is the main solution to meet the challenge of climate change (Newell & Pizer, 2008). More recently, the study of Sohag *et al*. (2015) concluded that economic growth and openness of trade increase the intensity of energy consumption while technological innovation is said to increase the energy efficiency and reduce the energy consumption, and Ali et al. (2016) claimed that technological innovation (patent applications) reduces CO_2 emissions, thus, improves the environmental quality.

On the other hand, there are some studies having the contradictory results regarding the role of technological change in an environmental scenario that technological innovation does not significantly affect the environmental quality (Parry, 2003; Smulders & Nooij, 2003). The introduction of technology as an endogenous factor open the ways for better economic growth and efficient energy consumption. The literature on the environment shows that technological innovation can be applied to determine its impact on different dependent variables including energy consumption, CO_2 emissions, and economic growth (Chèze *et al.*, 2013; Greaker & Pade, 2009; Sohag *et al.*, 2015).

The study derived the CO_2 emission function from the endogenous growth model presented by Romer and is presented in the form below following Eq. (3.24)

$$CO_2 = f(EC, GDP_{pc}, GDP^2, TI, Trade) \quad (4.1)$$

This regression model can be converted into an econometric model by applying the log on both sides as follows:

$$lnCO_2 = \beta_0 + \beta_1\, ln\text{EC} + \beta_2\, ln\text{GDP} + \beta_3\, ln\text{GD}P^2 + \beta_4\, ln\text{TI} + \beta_5\, ln\text{Trade} + \mu \quad (4.2)$$

Where *EC* is the energy consumption measured in kilotons of oil equivalent per capita and is in line with the former studies (Azam *et al.*, 2015; Saboori & Sulaiman, 2013a; Sohag *et al.*, 2015). *TI* is the technological innovation and is measured in the form of the patent application (Ang, 2010a, 2010b; Bonilla *et al.*, 2014; Madsen & Andersen, 2010; Madsen *et al.*, 2010). The GDP is measured in constant $US 2005 (Azam *et al.*, 2015; Azlina *et al.*, 2014; Begum *et al.*, 2015; Saboori & Sulaiman, 2013a). GDP^2 is the squared term of per capita income used for the validation of the EKC. The literature revealed that new technology can be imported from another country via international trade and this technology can be used to reduce the environmental pollution. Similarly, the literature also has noted that international trade can be used as one of the determinants of CO_2 emissions (Demiral, 2016; Gu *et al.*, 2013; Hossain, 2011). The error term in the model is represented by $\boldsymbol{\mu}$. The literature indicates that there are no such prior studies covering the set of variables used in the present study in the context of Malaysia. Therefore, the outcomes of this study will largely contribute to the literature on the linkage analysis between technological innovation and CO_2 emissions for Malaysia and can be extended to the other countries in the region also. This study can be helpful in addressing the role of international trade in attracting the modern environment-friendly technology and affecting the CO_2 emissions. This study can also be helpful in understanding the role of the efficient use of energy consumption to prevent emissions. Based on the discussions in the literature the study hypothesized that:

H_1: Technological innovation will reduce the concentrations of CO_2 emissions in Malaysia.

H_2: Economic growth in Malaysia will deteriorate the environmental quality

H_3: EKC relationship between higher per capita income and CO_2 emissions is validated in Malaysia

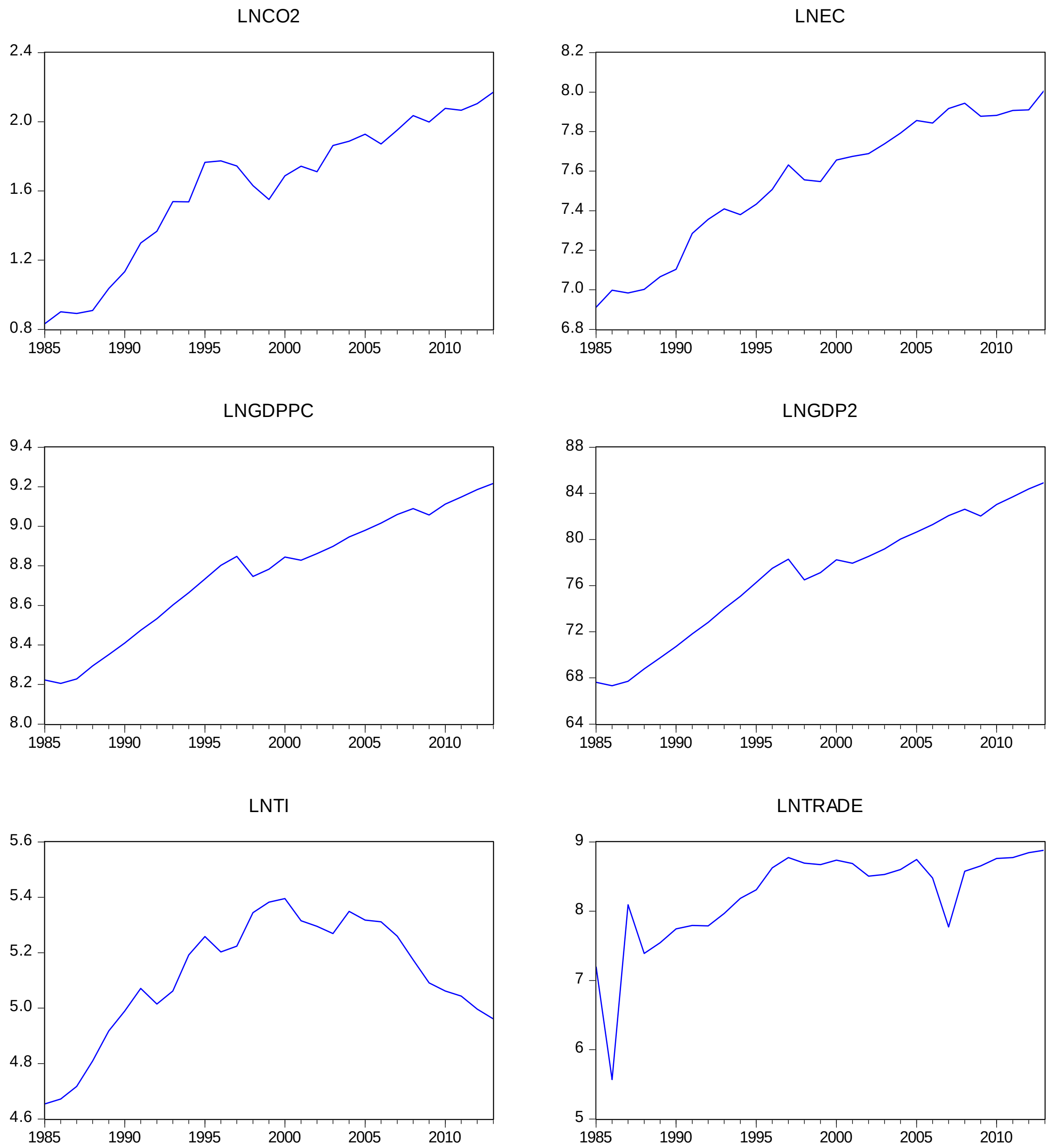
To validate these hypotheses and arrive at conclusions, the study employed the following procedure.

4.2.1 Unit Root Results (Objective 1)

The first step in determining that whether the model is ready for regression or not is to find out the stationarity properties of the series under investigation. The study applied the ADF, PP, DF-GLS and Ng-Perron Unit root tests to investigate the level of stationarity of all the variables of the study to further move towards regression analysis. The study applied all these four unit root tests in their intercept form and intercept and trend form to find out which type of unit root is there in the data.

One way to find out the presence of unit root is to draw the graph of the series and look for the presence of any trend in the data. The idea behind the test is, if there is any increasing or decreasing trend in the series shown in the graph, the series will be non-stationary. The study applied this method to the series in the model and concluded that all the variables except technological innovation are having unit roots in their level forms except for the technological innovation, which is stationary in its level form as there is no such clear trend in the series. The graphs of the series are shown in Fig. 4.1.

Figure 4.1: Graphs of the series in their Level Form



The unit root test of the model concludes that in the under the ADF test all the variables are non-stationary in their level form except technological innovation which is stationary at its level form. The results of the other unit root tests also confirmed the presence of unit roots in the series in their level form except for the technological innovation that does not have the unit root in its level form. The Results of the tests are presented in Table 4.1.

Table 4.1: ADF, PP, and DF-GLS Unit Root Test

Variables	**ADF Level**		**PP level**		**DF-GLS level**	
	Intercept	**Trend and intercept**	**Intercept**	**Trend and Intercept**	**Intercept**	**Trend and Intercept**
$LnCO_2$	-2.027	-1.108	-2.027	-1.108	-0.717	-1.338
LnEC	-1.709	-1.554	-3.231	-1.257	-0.175	-1.725
LnGDP	-1.074	-1.438	-1.094	-1.513	0.407	-1.507
$LnGDP^2$	-0.926	-1.624	-0.943	-1.547	0.473	-1.619
LnTI	-2.785*	-4.068**	-2.785*	-4.066**	-2.459**	-4.221**
LnTrade	-2.713	0.308	-2.713	-0.193	-1.330	-0.778
1st Diff. form	**Intercept**	**Trend and Intercept**	**Intercept**	**Trend and Intercept**	**Intercept**	**Trend and Intercept**
$LnCO_2$	-4.315***	-4.710***	-4.317***	-4.710***	-4.420***	-4.903***
LnEC	-5.164***	-5.013***	-5.228***	-7.224***	-4.990***	-5.275***
LnGDP	-4.680***	-4.891***	-4.676***	-4.979***	-4.098***	-4.629***
$LnGDP^2$	-4.781***	-5.009***	-4.780***	-4.914***	-4.212***	-4.693***
LnTrade	-3.310**	-4.603***	-3.285**	-8.236***	-3.380***	-4.921***

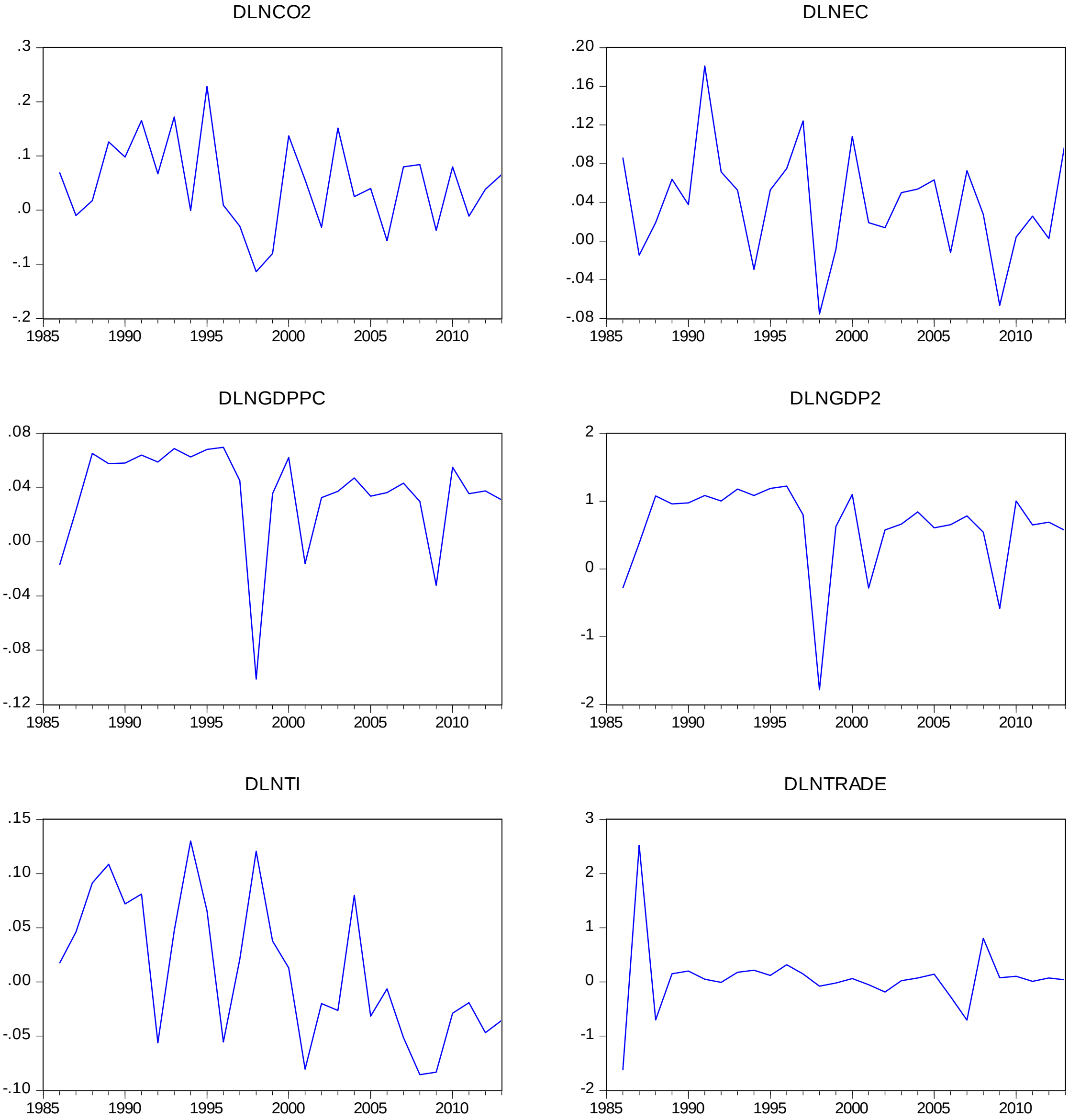
The results show that the test statistics values of the ADF, PP and DF-GLS are lower than those of the critical values at 1%, 5% and 10%, thus concluding that there is a unit root present in the series. In the case of the technological innovation, the study observed that the test-statistics value of the ADF, PP, and DF-GLS are greater than at least one of the critical values under 1%, 5% or 10% respectively. The study also applied the Ng-Perron unit root test to investigate the presence of a unit root before going for regression analysis. The study observed that similar to those of the ADF, PP, and DF-GLS test the series have unit roots in their level form except the technological innovations which are stationary a level form.

Table 4.2: NG-Perron Unit Root Test Results

Variables	NG-Perron Level Intercept				NG-Perron Trend and Intercept			
	MZ_a	MZ_t	MSB	MPT	MZ_a	MZ_t	MSB	MPT
$LnCO_2$	0.04956	0.04229	0.85333	42.9174	-3.57690	-1.09952	0.307	21.75
LnEC	0.73857	0.75724	1.02529	68.7405	-5.18401	-1.42121	0.274	16.78
LnGDP	1.24548	1.43236	1.15004	93.7953	-3.97864	-1.36709	0.343	22.36
$LnGDP^2$	1.29772	1.48254	1.14242	93.5660	-4.49856	-1.46863	0.326	19.99
LnTI	-7.787*	-1.888*	0.242*	3.448*	-12.97***	-2.54***	0.195***	6.55*
LnTrade	-0.77750	- 0.60431	0.77725	30.0108	-0.65257	-0.31900	0.488	53.172
1st Difference	**Intercept**				**Trend and Intercept**			
$LnCO_2$	-12.88*	-2.343*	0.181*	2.616**	-12.96**	-2.450**	0.189*	7.539*
LnEC	-12.77*	-2.50**	0.196*	2.00***	-24.63***	-3.50***	0.142*	3.699**
LnGDP	-11.96*	- 2.436**	0.203**	2.08***	-12.07**	-2.456**	0.203**	7.550*
$LnGDP^2$	-12.11**	- 2.449**	0.202**	2.06***	-12.19**	-2.468**	0.202**	7.478*
LnTrade	-11.33**	-2.33**	0.206**	2.323**	-397.8***	-14.1***	0.035***	0.229***

The results conclude that for all the variables except technological innovation the test statistics value of the MZ_a, MZ_t, and MSB are lower than the critical values at 1%, 5%, and 10%. On the other hand, the MPT values of the series are greater than the critical values at either 1%, 5%, or 10% indicating the presence of a unit root in the data except for technological innovation. The results of the Ng-Perron test are presented in Table 4.2. The study converted the series in their difference form to look for the unit root in the series at their first differences. The study concluded that the test-statistics value of all the test is greater than those of the critical values either at 1%, 5%, or 10%, thus, indicating the stationarity of the series at their first differences. The study thus concluded that all the variables are non-stationary in their level form and became stationary at their first differences as taking the differences of the series removes the trend from the data.

Figure 4.2: Graphs of the Series in their First-Differenced Form



The graphical representation of the unit root tests in their first difference-form also shows that variables are stationary in their difference-form. The graphs of the first difference-form of the variables show that the trend is removed from the data after taking the first difference of the series under the study. The results can be seen in Fig. 4.2.

4.2.2 ARDL General

An ARDL model is a type of least squares regression that use the lags of dependent and independent variables. The ARDL model is generally denoted by ARDL (p, q_1,……q_k). Where p represents the lags of the dependent variable, q_1 represent the number of lags of first independent variable and q_k represent the number of k-th independent variable. Some of the independent variables will not bear lags, thus, are known as fixed or static independent variables. The ARDL general is estimated in order to know the properties and lag selection of the model by the ARDL technique. This model carries both the short and long-term estimates of the model and is generally used to check if the model is viable or not.

In our study, the ARDL general model for first objective is as follows:

$$\begin{aligned}\Delta lnCO_{2t} = \beta_0 &+ \sum_{k=1}^{n} \beta_1 \Delta\, lnCO_{2(t-k)} + \sum_{k=0}^{n} \beta_{2k}\, \Delta lnEC_{t-k} + \sum_{k=0}^{n} \beta_{3k}\, \Delta lnGDP_{t-k} \\ &+ \sum_{k=0}^{n} \beta_{4k}\, \Delta lnGDP_{t-k}^{2} + \sum_{k=0}^{n} \beta_{5k}\, \Delta lnTI_{t-k} + \sum_{k=0}^{n} \beta_{6k}\, \Delta lnTrade_{t-k} \\ &+ \varphi_1 lnCO_{2(t-1)} + \varphi_2 lnEC_{t-1} + \varphi_3 lnGDP_{t-1} + \varphi_4 lnGDP_{t-1}^{2} \\ &+ \varphi_5 lnTI_{t-1} + \varphi_6 lnTrade_{t-1} + \epsilon_t \qquad (4.3)\end{aligned}$$

Where β_0 is the drift component in the equation and ϵ_t is the white noise. The error correction dynamics are represented by $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ and the long-run relationship is shown by $\varphi_1, \varphi_2, \varphi_3, \varphi_4, \varphi_5, \varphi_6$.

The estimation of the ARDL general is as follows:

Table 4.3: ARDL (1,1,0,0,0,1) General Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNCO2(-1)	0.252878	0.081681	3.095905	0.0059
LNEC	0.243645	0.264331	0.921742	0.3682
LNEC(-1)	-0.338196	0.127556	-2.651355	0.0158
LNGDPPC	19.97405	1.671891	11.94698	0.0000
LNGDP2	-1.070364	0.088654	-12.07352	0.0000
LNTI	-0.295329	0.070735	-4.175152	0.0005
LNTRADE	-0.037955	0.026501	-1.432202	0.1683
LNTRADE(-1)	-0.053435	0.015327	-3.486284	0.0025
C	-88.55590	7.456011	-11.87711	0.0000
		Diagnostic Tests		
R-squared	0.988778	**Mean dependent var**		1.649220
Adjusted R-squared	0.984053	**S.D. dependent var**		0.386823
S.E. of regression	0.048849	**Akaike info criterion**		-2.945064
Sum squared resid	0.045339	**Schwarz criterion**		-2.516856
Log likelihood	50.23090	**Hannan-Quinn criter.**		-2.814157
F-statistic	209.2577	**Durbin-Watson stat**		2.573768
Prob(F-statistic)	0.000000			
*Note: p-values and any subsequent tests do not account for model selection.				

4.2.3 ARDL Cointegration Test Results (Objective 1)

The second step after knowing the stationarity level and making the data stationary is to look for the presence of any cointegration between the variables in the long-run. The results of the unit root test concluded that all the variables of the study except the technological innovation are stationary at first differences, which is stationary at its level form. The results of the unit root test concluded that variables have different integration forms such as I (0) and I (1), thus, it is concluded to apply the Autoregressive distributed aged model bounds testing approach to find out the long-run cointegration. The Johansen cointegration test is not applicable to the data stationary at different levels, as it is only applicable when the variables are stationary at their first differences. The study, thus, applied the ARDL bounds test to investigate the presence of a long-run relationship between the variables of the study. The ARDL bounds testing approach have two critical bound values at different levels of significance i.e. at 1%, 5%, and 10% respectively. The null hypothesis of the test is if the calculated F-statistics value is greater than the upper bound value at the level of significance there will be long-run cointegration in the series and vice versa. The results of the study concluded that in the case where CO_2 emissions are dependent variable the value of the F-statistics of the bounds test is 4.42 and is well above the upper bound critical values at 10% and 5%. Thus, the study concluded that there is long-run cointegration present in the variables of the model. The results of the ARDL bound test are presented in Table 4.4.

The study applied the same technique, making every variable the dependent variable to check for the presence of any cointegration between the variables in the long-run and concluded that all the models are integrated into the long-run except where energy consumption is the dependent variable. The conclusion is based on the F-statistics value as it is below the lower bound critical value even at the 10% level of significance. An alternative way to find out the presence of the long-run integration in the model is to look for the value of the cointegrating equation error term. The idea behind the test is that if the ECM_{t-1} value is negative and significance the model is said to be integrated into the long-run. The study also considered this test to look for the presence of long-run integration between the variables of the model and found that all the models have long-run cointegration. The model with energy consumption as dependent variables does not have a long-run relationship between the variables because the F-statistics are well below the lower bound critical value even at the 10% level of significance. This test decided about the presence of a long-run relationship between the variables if the F-statistics value of the bound test fall between the lower and upper bound critical values and the result is inconclusive then the negative and significant value of ECM_{t-1} decides about the presence of long-run integration.

Table 4.4: The ARDL Results of Cointegration

Model	ARDL (AIC 1 Lag)	F-statistics	ecm_{t-1} (t-statistics)	Conclusion
FlnCO₂ **($LnCO_2$/ lnEC LnGDPpc LnGDP^2 LnTI LnTrade)**	(1 1 1 0 0 1)	3.9192**	-0.87(-4.40) ***	**Cointegration**
Critical values	**Lower Bound I(0)**	**Upper Bound I(1)**		
10%	2.26	3.35		
5%	2.62	3.79		
1%	3.41	4.68		

4.2.4 ARDL Long-run Results (Objective 1)

The cointegration test of ARDL bounds determined the presence of a long-run relationship between the variables of the model. The study then applied the cointegration tests under ARDL based on OLS to find out the extent of the long-run relationship. The long-run results of the model can be estimated under the following equation.

$$lnCO2 = \gamma_0 + \gamma_1 lnEC_t + \gamma_2 lnGDP_t + \gamma_3 lnGDp^2{}_t + \gamma_4 lnTI_t + \gamma_5 lnTrade_t + \mu_t \quad (4.4)$$

Where $\gamma_0 = \frac{\alpha_0}{1-\sum\alpha_{1i}}, \gamma_1 = \frac{\alpha_{2i}}{1-\sum\alpha_{1i}}, \gamma_2 = \frac{\alpha_{3i}}{1-\sum\alpha_{1i}}, \gamma_3 = \frac{\alpha_{4i}}{1-\sum\alpha_{1i}}, \gamma_4 = \frac{\alpha_{5i}}{1-\sum\alpha_{1i}}, \gamma_5 = \frac{\alpha_{6i}}{1-\sum\alpha_{1i}}$.

The long-run results of the study claim that energy consumption increases the environmental pollution as the coefficient of the energy consumption bears a positive sign. The study also concluded that this deteriorating impact of energy consumption on the environment is insignificant, meaning that energy consumption is one of the reasons for environmental pollution among the other determinants and is not the sole reason of polluting the environment. Malaysia as a transitional economy is dependent mainly on the non-renewable energy resources like oil, natural gas and coal rather than renewable energy resources, so the country emits a huge amount of CO_2 into the atmosphere polluting the environment. The outcome of the study supports the previous work of Shahbaz *et al*. (2013) in Indonesia, Ali *et al.* (2016), Begum *et al*. (2015), and Saboori & Sulaiman (2013b) in Malaysia. This outcome infers that in the existing setup in the country, it is difficult for the government to decouple the carbon emissions. Thus, alternative way to reduce emissions is to encourage some policy reforms to overhaul the structure of energy consumption in the economy and to reassure the installations of environment-friendly and energy efficient technologies.

The main outcome of the study is related to the role of technological innovation in the environmental perspective. The study used patent applications to investigate the impact of its increase in the environmental quality, and concluded that technological innovation improves the quality of the environment as the coefficient bears a negative sign. The study concluded that an increase of 1% in the technological innovation would lead to a decrease of 0.39% in the CO_2 emissions in the long-run. This outcome of the study can be because of the improvement in the energy efficiency due to the use of more advanced and environment-friendly technology in the process of production. The environmental quality in Malaysia can be improved if the government regulatory bodies encourage and persuade the manufacturers to install new environment-friendly technology for the production purposes. The study results are in line with the previous work of Ali et al. (2016) in Malaysia, Ahmed *et al*. (2016) for selected European countries, and Sohag *et al*. (2015) in Malaysia, where they conclude that technological innovation reduces energy intensity and CO_2 emissions. The study concluded that improved technology along with efficient use of energy could improve the quality of the environment. In the case of economic growth, the study found the very consistent and general result that economic growth increases the concentration of CO_2 emissions in the atmosphere as economic activities emit GHG, especially carbon dioxide in the atmosphere. The study concluded that while performing economic activities the manufacturers are using non-renewable energy resources, which leads to the emission of the CO_2, thus, polluting the environment. This outcome of the study can be justified as the country is in the phase of transition from developing to developed nations, so the main aim of the government is to keep the pace of economic growth up to the mark to achieve the status of a developed nation by 2020. The country consumes a lot of energy resources for its economic growth, which emits a huge amount of CO_2, thus the study concludes that if there will be a 1% increase in the current rate of economic growth it will be at the cost of an increase in the CO_2 emissions by 26.73%. The results suggest that the country should look for more renewable energy resources and should adopt the energy efficiency measures to reduce the environmental pollution level while growing at the same pace. This result of the study is similar to the previous work of (Alam *et al*., 2015; Ali *et al*., 2016; Begum *et al*., 2015b; Saboori & Sulaiman, 2013b) among others in Malaysia. The results of the ARDL long-run are depicted in Table 4.5.

Table 4.5: ARDL Long-run Results

Regressors	**Coefficient**	**Standard Error**	**T-Ratio**	**Probability**
LNEC	0.126554	0.218083	0.580304	0.5685
LNGDPPC	26.734650	0.909259	29.402671	0.0000
LNGDP2	-1.452649	0.064126	-22.65042	0.0000
LNTI	-0.395289	0.107040	-3.692904	0.0015
LNTRADE	-0.122322	0.051073	-2.395039	0.0271
C	-118.529349	4.105792	-28.868818	0.0000
EKC Proof	**$-\beta_3/2\beta_4$** **-GDPpc/ 2GDP2**	**Threshold Value**	**LnGDP Highest value**	**Conclusion**
Turning point	-26.734650/ 2(1.452649)	**9.20203364= US$9917.277**	**9.21680017= US$10064.81**	**EKC validated**

Moreover, the study also investigated the presence of the environmental Kuznets curve hypothesis between per capita income and CO_2 emissions in Malaysia. The study results found that the squared term of GDP bears a negative sign, thus, concluding that higher economic growth can improve the quality of the environment by reducing the intensity of CO_2 emissions in the atmosphere. The study concludes that an increase of 1% in the high economic growth will cause a decrease of 1.45% in the CO_2 emissions in the long-run, thus confirming the necessary element of the EKC hypothesis that higher income reduced the environmental pollution by investing more in the renewables and environment-friendly technology. The essential part of the EKC hypothesis is the threshold value of the turning point of the inverted U-shaped curve. The study concluded that the threshold value of the turning point is US$9917.277, which is well in the range of the per capita income where the highest value is US$10064.81. Thus, the study confirmed the validation of the EKC hypothesis in the long-run in the case of Malaysia over a period 1985 to 2013. This result reveal that even with the same amount of energy consumed in the country the turning point can fall within the range of the current per capita income if advanced, environment-friendly, and energy efficient technology is employed in the manufacturing and production sectors of the economy.

The study further investigated the impact of trade openness on the quality of the environment and concluded that the coefficient of trade openness bears a negative and the impact on the environment is significant. An increase in international trade in Malaysia in the long-run can significantly improve the environmental quality. The results concluded that international trade in Malaysia is somewhat environment-friendly, the government further should focus more on the less pollutive imports and the trade should be more exports based to avoid the imports of polluting goods and services. The negative impact of trade on CO_2 in this model is because of the involvement of the advanced technology in the production in the domestic industries, thus, the production become more energy efficient and less polluting. The technique effect of trade came into play when trade and advanced technology moves side by side in long-run. This outcome in the case of trade openness is in line with the work of Shahbaz *et al*. (2012a) for Pakistan, and Sebri & Ben-Salha (2014) for BRICS countries.

4.2.5 ARDL Short-run Results (Objective 1)

The study also focused on the short-run outcomes of the analysis because of the importance of the short-term actions to reduce the environmental pollution. The short-run results of the model can be estimated under the following equation.

$$\Delta lnCO_{2t} = \alpha_0 + \sum_{k=1}^{n} \alpha_{1k}\, \Delta lnCO_{2(t-k)} + \sum_{k=1}^{n} \alpha_{2k}\, \Delta lnEC_{t-k} + \sum_{k=1}^{n} \alpha_{3k}\, \Delta lnGDP_{t-k} + \sum_{k=1}^{n} \alpha_{4k}\, \Delta lnGDP_{t-k}^{2} + \sum_{k=1}^{n} \alpha_{5k}\, \Delta lnTI_{t-k} + \sum_{k}^{n} \alpha_{6k}\, \Delta lnTrade_{t-k} + \theta ECT_{t-1} + \epsilon_t \quad (4.5)$$

The short-run results of the study concluded that energy consumption increases the environmental pollution because the country is dependent on the non-renewable energy consumption to carry out the economic activities. Malaysia is dependent on the use of coal, gas, and oil for the production process and manufacturing purposes and consumes a huge amount of these non-renewables energy resources, thus, causing an increase in the atmospheric CO_2 emission in the country. The impact of energy consumption on the environmental pollution is positive, but insignificant as energy consumption is one of the culprits responsible for the increase in the environmental pollution among other factors, such as economic growth, deforestation, and transportation in the country. The study confirmed that other determinants are also playing a vital role in polluting the environment. The study also focused on the impact of economic growth on the environment and noted that economic growth is positively related to the CO_2 emissions in Malaysia in the short-run. The result concluded that if there will be an increase of 1% in the rate of growth of the economy, it will cost the country with an increase in CO_2 emissions by 19%. This impact of the economic growth is very high as economic activities involve the emissions of CO_2 during the production process. Economic growth is considered as one of the main contributors to the environmental pollution because it draws the energy resources like coal, oil, and gas to perform the economic activities to boost the economic growth. This boost in the economic growth, then comes at the expense of environmental quality (Ali et al., 2016; Begum et al., 2015; Saboori & Sulaiman, 2013b).

Table 4.6: ARDL Short-run Results

Regressor	**Coefficient**	**Standard Error**	**T-Ratio**	**Probability**
D(LNEC)	0.243645	0.264329	0.921749	0.3682
D(LNGDPPC)	19.974050	1.670718	11.955366	0.0000
D(LNGDP2)	-1.070364	0.088584	-12.083054	0.0000
D(LNTI)	-0.295329	0.070720	-4.176025	0.0005
D(LNTRADE)	-0.037955	0.026501	-1.432208	0.1683
CointEq (-1)	-0.747122	0.081677	-9.147260	0.0000
EKC Proof	**$-\beta_3/2\beta_4$**	**Value**	**LnGDP Highest value**	**Conclusion**
Turning point	-19.974050/ 2(-1.070)	9.3304941= US$11276.7	9.21680017= US$10064.81	**EKC Not Validated**

The study also focused on the role of technology in the short-run in the case of Malaysia and concluded that increase in the patent applications can reduce the environmental pollution even in the short-run. In the short-run, the impact of technological innovation is a bit small but is significant enough to reduce some percentage of CO_2 emissions in the atmosphere in the country. The study claimed that an increase of 1% in the patent applications in Malaysia in the short-run would decrease the environmental pollution by reducing the CO_2 emissions by 0.29%. This outcome shows that technological innovation in Malaysia is in the stage of infancy and needs to be boosted to its peak to reduce the environmental pollution by targeting the reduction of CO_2 emissions. The results of the short-run ARDL are presented in Table 4.6.

The short-run results of the study revealed that higher economic growth can reduce the CO_2 emissions even if it is in the short or long-run. The results concluded that if there will be an increase of 1% in the rate of the higher income in the economy, it will lead to a decrease in the CO_2 emissions in the country by 1.07% in the short-run. The study further concluded that bearing negative sign, the higher economic growth form an inverted U-shaped relationship with the CO_2 emissions in Malaysia, thus, confirming the validation of EKC hypothesis. The study noted that the threshold value of the turning point in the short-run is US$11276.7, which is well below the higher value of US$10064.81 for the per capita real GDP, which confirms that the turning point fall inside the per capita income of Malaysia and is acceptable. This outcome posits that when modern, environment-friendly, and energy efficient technology is involved in the manufacturing, trading, and services sectors of the economy, even in the short-run the turning point can be achieved. The study concludes that the number of patent applications in the country has increase and the government is also involved in import of energy efficient technology, thus, the ultimate outcome will be in the favor of improving environmental quality. The study also concluded that trade openness improves the environmental quality even in the short-run. These results posted that in Malaysia the international trade is less polluting and the imports and exports of the country are well managed to ensure the environmental quality. The country exports the raw material and manufactured products that are less polluting and the imports include the environment-friendly products and technology, which helps improve the environment.

4.2.6 Diagnostic Test Results (Objective 1)

The study applied the diagnostic test to check the model if it fits for regression or not. The study observed the value of R^2 find out how much of the variation in the dependent variable are due to the independent variables and noted the value of R^2 is 0.74. The study, thus, concluded that 70% of the variations in CO_2 emissions are due to the changes in the independent variables of the model. This result concluded that this model is a good fit for regression and the estimates of the study are efficient. The study also observed the value of 0.61 of the adjusted R-square and concluded that both the R^2 and adjusted R^2 confirmed the goodness of fit of the model. The adjusted R^2 value is below R^2 the predicted change is less than the expected change due to the inclusion of new variables in the model. The study also focused on the overall goodness of the model by considering the value of F-statistics and its probability value of 5.82 and 0.000 respectively that are well in the range of goodness of fit of the model, so the study accepted the overall model for regression and forecasting. The study also analyzed the Durbin-Watson statistics to confirm that there is no problem of autocorrelation in the model. The DW-statistics value of 2.28 shows that the model is free from the problem of autocorrelation problem and the model is also not a spurious model because the value of DW-statistics is well above the value of R^2. The standard error and the residuals sum of squares of small values support the results that model is a good fit and well estimated. Furthermore, the study applied the Breusch-Pagan Godfrey serial correlation test to investigate the presence of serial correlation and concluded that there is no serial correlation between the variables of the model. The probability values of both LM (0.78) and F-version (0.87) are greater than 0.05 so both tests of serial correlation show that the model is free of the serial correlation problem, which is a good sign for the efficient estimation of the results. The results of the diagnostic tests are presented in Table 4.7.

Table 4.7: Diagnostic Tests

R^2	0.744499	**DW-statistic**	2.286714
Adjusted R^2	0.616749	**S.E. of Regression**	0.050414
F-Statistics (Prob.)	5.827760 (0.0007)	**RSS**	0.045748
Test-Statistics	**LM version**	**F Version**	**Conclusion**
Serial Correlation (Chi SQ)	0.483154(0.7854)	0.140468(0.8700)	**No Serial Correlation**
Functional Form (Chi SQ)	1.390 (0.238)	1.232394(0.3178)	**Correct functional Form**
Jarque-Bera (Chi SQ)	2.4759(0.2899)	Not Applicable	**Normally Distributed**
Heteroscedasticity (Chi SQ)	7.940258(0.5402)	0.791661(0.6280)	**No Heteroscedasticity**

Moreover, the study focused on the functional form of the model by considering the value of the RESET test for functional form and the test confirmed that the functional form of the model is correct with a value of 1.390 and a probability value of 0.238 that is well above the rejection level of the null hypothesis. Similarly, the F version of the test also confirmed that the model has correct functional form. Data normality is considered as one of the most important aspects to arrive at good and efficient estimates of the model. The study applied the Jarque-Bera test of normality and concluded that the data is normally distributed with a value of 2.47 and probability value of 0.289, which is well above the rejection level of the null hypothesis of the normal distribution of the residuals of the data. The study further tested the model for the problem of heteroscedasticity in the data and found that the variances of the data are distributed at equal distances and are spread with equal distances. The study thus concluded that there is no heteroscedasticity problem in the model. The entire model diagnostic test confirmed that the model is viable and suitable for the regression and the estimates of the model are correct and efficient.

4.2.7 Ramsay's RESET and Omitted Variables Likelihood Ratio Test for Model Specification (Objective 1)

Beside the above diagnostic test for the validity of the model, the study also applied Ramsay's regression error specification estimation test (RESET) to investigate the functional form of the model and to look for the omitted variable if any in the model. The RESET test is used to find out if the functional form of the model is correct and it specifies the squares and cubes of the fitted values and checks if they belong to the model but missed out while constructing the model. The RESET test results concluded that the functional form of the model is correct because the F-statistics value of the model and a probability value of 0.317 is well above the rejection point of the null hypothesis of the correct functional form of the model. The study also investigated the possibilities of the omitted variables and constructed the squares and cubes of the fitted values as an extra variable to check if they belong to the model. The results of the RESET test concluded that these variables do not belong to the model, as they have no significant impact on the dependent variable of the study. The probability values of these fitted variables are 0.88 and 0.87 respectively, which are insignificant, thus, cannot reject the null hypothesis that these variables are significantly zero. Results are depicted in Table 4.8.

The study also applied the omitted variable likelihood ratio test to find out if there is any necessary variable omitted from the model during the construction of the model. The study entered the financial development as the necessary variable that is omitted during the estimation process and concluded that financial development in not a necessary variable left out of the current model. The likelihood ratio and the probability F-statistics values of 0.59 and 0.49 are much higher than 5% to reject the null hypothesis that financial development is significantly zero and have no significant impact on the dependent variable in the current model. The study also noted the coefficient of the financial development and the probability value of 0.31 of the coefficient claimed that financial development has no significant impact on the CO_2 emissions in this model. The study, thus, confirmed that the estimates of the current model are efficient and this model is fit for future forecasting.

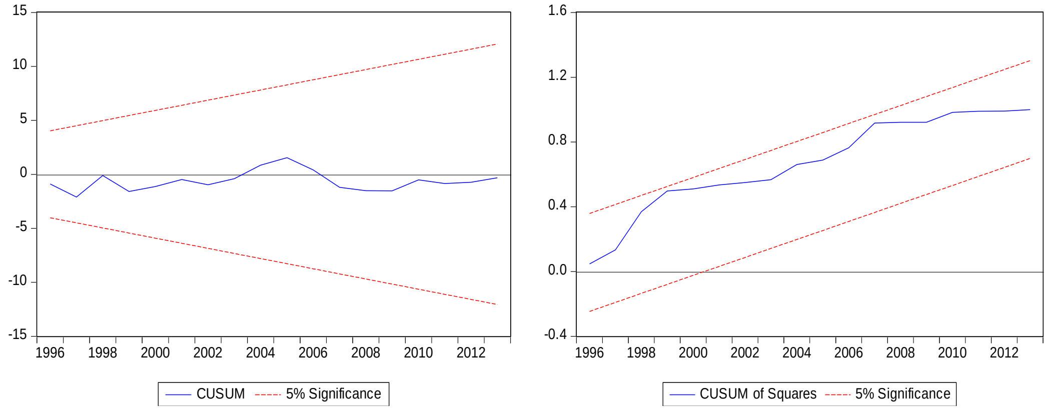
Table 4.8: Ramsay RESET and Omitted Variable Likelihood Ratio Tests

F-statistic	**Value**	**Probability**	
	1.232394	0.3178	
Omitted Variable Likelihood Ratio Test	**Value**	**Probability**	
F-statistics	0.289551	0.5975	
Likelihood Ratio	0.472892	0.4917	
Omitted variables	**Coefficient**	**Standard Error**	**Probability**
FITTED^2	2.414822	16.25983	0.8838
FITTED^3	-0.617172	3.982624	0.8788
LnM2	0.034949	0.033924	0.3173

4.2.8 CUSUM and CUSUMSQ Tests Results (Objective 1)

The study applied the cumulative sum of recursive residuals and the cumulative sum of squares of recursive residuals to find out if there is any breaking point in the data like structural change. The CUSUM test concluded that the model has no structural breaks and the model is stable because the errors of the recursive residuals fall inside the critical line at the 5% level of significance. Similarly, the results of the CUSUMSQ test also concluded that the model is stable as the cumulative sum of squares of recursive residual errors are well inside the critical line at the 5% level of significance.

Figure 4.3: Graphs of CUSUM and CUSUMSQ Results



4.3 Objective Two of the Study: To investigate the impact of Structural Changes in the economy on the Environment in Malaysia

Environmental degradation has become the center of discussion due to the continuous emissions of GHGs in the atmosphere, especially the carbon dioxide. The concentration of CO_2 emissions is increasing at a fast pace in the atmosphere which leads to the warming of the Earth's climate. The global warming thus has deleterious consequences in the shape of climate change, and ultimately the human race and other species will be affected. The climate change can bring about abrupt changes in the patterns of rainfall, crops, droughts, floods, the rise in the sea level, and other calamities that can harm the humanity. Many researchers have focused on the economic growth, energy consumption, trade openness, financial development and other different variables, but there is no clear conclusion about their relationship. Some researchers also focused on the transition of the economies from developing to developed economies as there increase the industrial activities in the phase of transition. One of the objectives of the current thesis is to explore the impact of structural change in the economy on the environmental quality of Malaysia. To cope with this objective, the study focused on the industry value added (INVAD) which is a proxy used to measure the structural change in the economy (Kaivo-oja *et al.*, 2014; McMillan & Rodrick, 2011; Pasche, 2002; Vaseghi & Esmaeili, 2010). The study included economic growth, energy consumption, and trade openness as other potential determinants of CO_2 emissions. The study also included the population growth as a control variable to check for its impact on the quality of the environment. The period of the current study is 1971-2013 annual time series data. The study emphasized on Eq. (3.23) and hypothesized that:

H_4: Structural changes in the economy will improve the environmental quality in Malaysia

H_5: EKC relationship between higher per capita income and CO_2 emissions is validated in Malaysia

H_6: Trade Openness will deteriorate the environmental quality

4.3.1 Unit Root Test (0bjective 2)

The first step in analyzing any time series data set is to look for the stationarity properties of the series to proceed for further analysis. The unit root test decides the application of the econometric technique for analyzing the model. This thesis applied ADF, PP, DF-GLS and Ng-Perron Unit root test to find out the presence of any unit root in the data. The current model shows that the data are having unit root in the variables in their level form as illustrated in Figure 4.4(a)…4.4(g). The data is showing a clear increasing trend that is the evidence of the presence of a unit root in the level form.

Figure 4.4: Trends of the Series in their level form

Figure 4.4 (a): Trend of CO_2 emissions

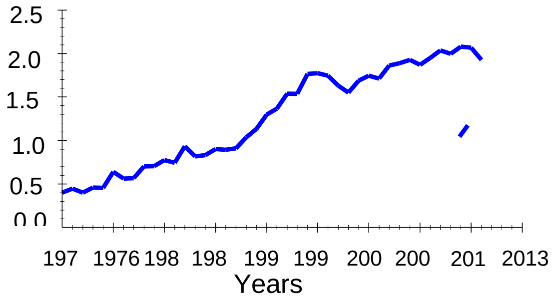


Figure 4.4(b): Trend of Energy consumption

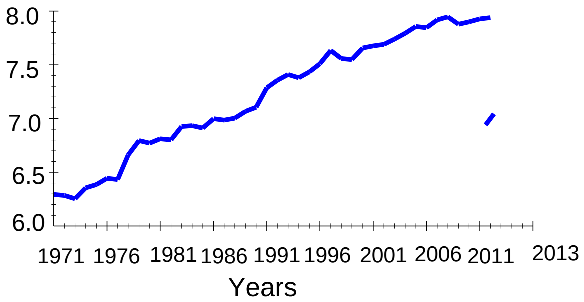


Figure 4.4 (c): Trend of GDP_{PC}

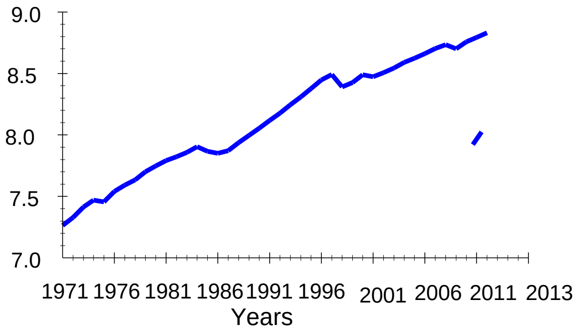


Figure 4.4 (d): Trend of GDP^2

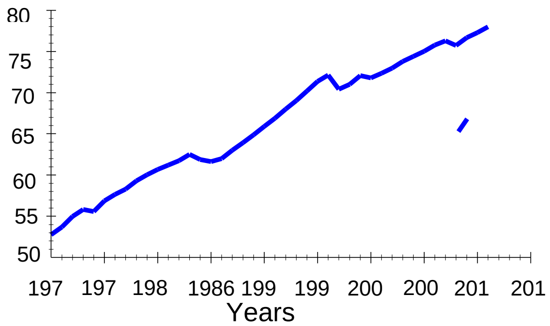


Figure 4.4 (e): Trend of Trade openness

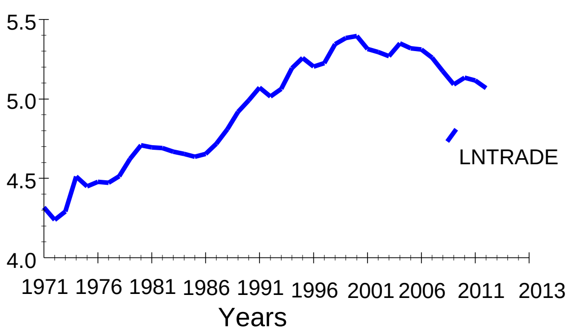


Figure 4.4 (f): Trend of Structural Change

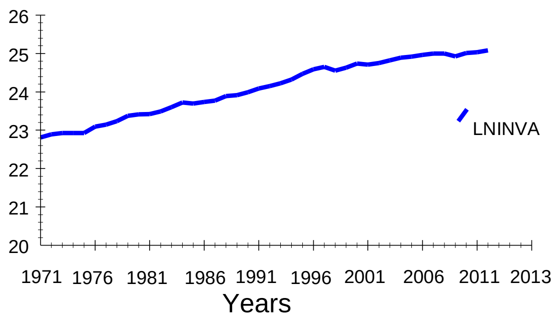
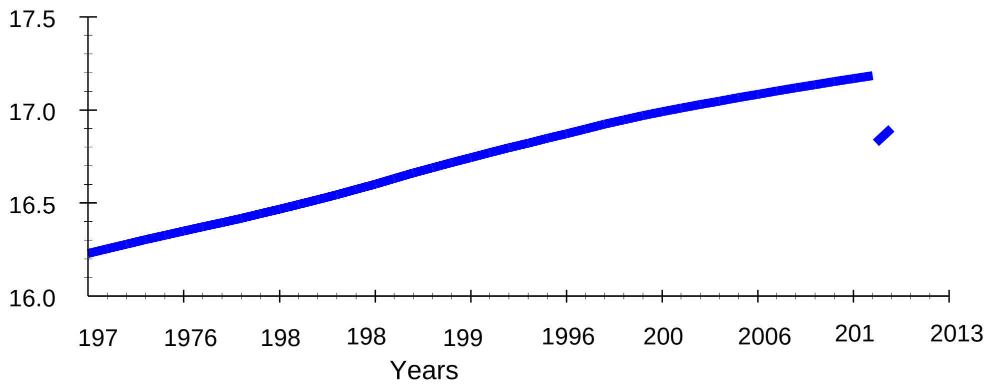


Figure 4.4 (g): Trend of Total Population



Alternatively, the results of the unit root test also show that the variables have unit roots in their level form, and only population is stationary at a level under 10% level of significance. All the results of the three tests of ADF, PP and DF-GLS are shown in Table 4.9.

Table 4.9: ADF, PP, and DF-GLS Unit Root Test

Variables	**ADF Level**		**PP level**		**DF-GLS level**	
	Intercept	**Trend and intercept**	**Intercept**	**Trend and Intercept**	**Intercept**	**Trend and Intercept**
lnCO_2	-1.004255	-1.856897	-1.004255	-1.856897	0.253214	-2.059868
lnGDP	-1.563286	-2.216848	-1.520098	-2.333951	0.811148	-1.906875
lnGDP^2	-1.153897	-2.279667	-1.130119	-2.423458	0.890705	-2.129062
lnEC	-1.156357	-1.862791	-1.753222	-1.899010	0.816072	-2.090009
lnTrade	-2.341868	-0.185181	-1.805025	-0.039223	-0.915675	-1.215360
lnInvad	-1.483102	-0.854397	-1.702818	-0.746050	0.673736	-1.173208
lnPop	-2.805169*	-3.444305*	-2.323680*	-3.523623*	-2.502512*	-5.57552**
1st Difference	**Intercept**	**Trend and Intercept**	**Intercept**	**Trend and Intercept**	**Intercept**	**Trend and Intercept**
ln CO_2	-7.1147***	-7.0733***	-7.1011***	-7.0733***	-7.1343***	-7.0575***
lnGDP	-5.5014***	-5.5754***	-5.4677***	-5.5758***	-5.1584***	-5.68466
lnGDP^2	-5.6255***	-5.6202***	-5.6247***	-5.6213***	-5.4189***	-5.7436***
lnEC	-6.6860***	-6.8244***	-6.8747***	-9.5709***	-5.9997***	-6.6256***
lnTrade	-5.1999***	-5.8826***	-5.223***	-5.9182***	-3.9825***	-5.0484***
lnInvad	-5.9042***	-6.0867***	-5.8913***	-6.2177***	-5.9011***	-6.2450***
Note: *, **, and * represent the significance level at 10%, 5%, and 1% respectively.**						

The results show that like the graphs if trends in the study variables the ADF, PP, and DF-GLS test statistics are lower than those of the critical values of the test thus cannot reject the null hypothesis of a unit root in the series. While the ADF, PP, and DF-GLS test statistic's values are greater than the critical values of the test in the case of population, thus, rejecting the null hypothesis of the presence of a unit root in the series. Thus, the results conclude that all the variables except population are non-stationary at levels and become stationary after taking the first differences of the series. The results in Table 4.9 show that in the first-difference form the ADF, PP, and DF-GLS test statistics values are greater than the critical values of the test, thus rejecting the null hypothesis of the presence of a unit root in the model. Table 4.10 shows the unit root results of NG-Perron unit root test. The test displays that all the variables are stationary at first-differences while they show unit root in their level forms.

Table 4.10: NG-Perron Unit Root Test Results

Variables	**NG-Perron Level Intercept**				**NG-Perron Trend and Intercept**			
	MZ_a	**MZ_t**	**MSB**	**MPT**	**MZ_a**	**MZ_t**	**MSB**	**MPT**
ln CO_2	0.662	0.679	1.024	67.75	-8.210	-1.843	0.224	11.62
lnGDP	1.162	1.048	0.901	59.59	-4.712	-1.600	0.280	14.76
$lnGDP^2$	1.260	1.151	0.913	62.13	-7.164	-1.843	0.257	12.79
lnEC	1.131	1.481	1.308	117.25	-8.405	-1.862	0.221	11.42
lnTrade	-0.597	-0.423	0.708	27.33	-4.123	-1.144	0.277	19.19
lnInvad	0.97376	0.973	0.999	69.053	-3.712	-1.1091	0.298	21.03
lnPop	0.69401	0.481	0.694	35.040	2.243	2.3752	1.058	289.62
1st Difference	**Intercept**				**Trend and Intercept**			
ln CO_2	-19.33***	-2.96***	0.15***	1.77***	-19.52***	-3.03***	0.15***	5.22***
lnGDP	-19.18***	-3.09***	0.16***	1.28***	-19.78**	-3.13**	0.15**	4.63**
$lnGDP^2$	-19.54***	-3.12***	0.15***	1.25***	-19.83**	-3.14**	0.15**	4.62**
lnEC	-19.86***	-3.15***	0.15***	1.23***	-19.71**	-3.13**	0.15**	4.65**
lnTrade	-16.11***	-2.83***	0.17***	1.53***	-18.24**	-3.00**	0.16**	5.10**
lnInvad	-19.91***	-3.15***	0.15***	1.23***	-19.99**	-3.16**	0.15***	4.56***
lnPop	-5.9167*	-1.483	0.25*	4.829*	-17.40**	-2.90*	0.166*	5.525*
Note: *, **, and * represent the significance level at 10%, 5%, and 1% respectively.**								

4.3.2 Cointegration Results (Objective 2)

Considering the results of unit root test the study reveals that all the variables are integrated of order I (1), so to find out the cointegration relation between the variables the study applied the Johansen cointegration technique and ARDL bound testing approach.

4.3.2.1 Johansen Cointegration Test

The Johansen cointegration technique is applied when all the variables of the study are integrated of order I (1). There are two tests under Johansen cointegration test to detect the presence of a cointegration relationship between the variables of the study. One test of cointegration is the Trace statistics, and the other is the maximum-Eigenvalue statistics test. The results of the Johansen cointegration test are shown in Table 4.11.

The trace statistics results indicate that there are three cointegrating equations as the trace statistics values are higher than the 0.01 critical values up to at most two cointegrating equations bearing the value 85.24 which is greater than the critical value of 77.81. The study thus rejected the hypothesis that there are at most two cointegrating equations and concludes that there are at most three cointegrating equations in the model which confirms the presence of a long-run relationship between the variables of the study.

On the other hand, the maximum eigenvalue results of the Johansen test reveal that there are at most two cointegrating equations as the test rejects the hypothesis of at most one cointegrating equations with a maximum eigenvalue of 52.82 which is greater than the critical value of 45.86 at 0.01 level of significance. The study, therefore, accepts the hypothesis of at most two cointegrating equations under the maximum eigenvalue statistics. The presence of these cointegrating equations confirms the presence of the long-run relationship between the study variables. There are two lags selected for the model, and the Johansen test is estimated using two lags as suggested by both the Schwarz information criterion (SIC) and Akaike Information Criterion (AIC).

Table 4.11: Johansen Cointegration Results of Trace Statistic and Maximum-Eigenvalue

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.01 Critical Value	Prob.**
None *	0.917019	251.1708	133.57	0.0000
At most 1 *	0.665658	149.1158	103.18	0.0000
At most 2 *	0.608796	104.1965	76.07	0.0000
At most 3*	0.572505	65.71694	54.46	0.0005
At most 4	0.368781	30.87464	35.65	0.0375
At most 5	0.222447	12.01041	20.04	0.1564
At most 6	0.040491	1.694689	6.65	0.1930
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.01 Critical Value**	**Prob.****
None *	0.917019	102.0550	51.57	0.0000
At most 1	0.665658	44.91927	45.10	0.0132
At most 2	0.608796	38.47961	38.77	0.0131
At most 3	0.572505	34.84231	35.24	0.0249
At most 4	0.368781	18.86422	25.52	0.1009
At most 5	0.222447	10.31572	18.63	0.1920
At most 6	0.040491	1.694689	6.65	0.1930

Note: Trace Statistics indicates 4 cointegrating equations at the 0.01 level
Max-Eigenvalue test indicates 1 cointegrating equations at the 0.01 level
* Represents the rejection of hypothesis at the 0.01 level
** Represents the Mackinnon-Haug-Michelis (1999) p-values

4.3.2.2 ARDL Cointegration Test

An alternative and more robust test of cointegration is the bounds test of the autoregressive distributed lagged (ARDL) model. The bounds test is used to find out the cointegrating relationship between the variables of the model. There are two ways to detect the presence of long-run integration between the variables of the study under bound testing approach. One way is the comparison of the value of the F-statistics of the bound test with the lower and upper bound values of Pesaran *et al.* (2001) table of critical values of upper and lower bounds.

Another way to find out the presence of the cointegrating relationship between the variables is the error correction term (ECT_{t-1}) value. It is argued that if the value is negative and significant, it indicates the presence of a long-run relationship between the variables under the study. The study selected the ARDL model with two lags as suggested by the Akaike information criterion (AIC), which is one of the most general lag selection criteria alongside SIC and others. The ARDL cointegration test results conclude the presence of the long-run relationship between the variables of the study. The results of the test are given in Table 4.12.

Table 4.12: ARDL Cointegration Results

Model	**ARDL (AIC 2 lags)**	**F-statistics**	**ECT_{t-1} (t-statistics)**	**Conclusion**
FlnCO₂ (Ln *CO₂*/ lnEC LnGDPpc LnGDP^2 LnInvad LnTrade LnPop)	(1 2 0 0 2 2 1)	3.53*	-0.411 (-2.0938) **	Cointegration
Critical values	**Lower Bound I(0)**	**Upper Bound I(1)**		
10%	2.12	3.23		
5%	2.45	3.61		
1%	3.15	4.43		

In the case of the CO_2 as a dependent variable in the first model, there is a long-run relationship between the variables as the value of the F-statistics is greater than the upper bound value and this result is confirmed by the negative and significant value of the error correction term (ECT_{t-1}). The results also reveal the presence of a long-run relationship between the variables in all the models as their F-statistics values are greater than the upper bound values except the model where trade is the dependent variable. In this case, the value of the F-statistics lie between the upper and lower bound value at 5% and 10% level of significance. Thus, we cannot conclude whether there is any long-run relationship between the variables or not. It is argued that there is a long-run relationship between the variables if the error correction term is negative and significant. Thus, the study concludes that there is a long-run relationship between the variables of the study.

4.3.3 ARDL General

An ARDL model is a type of least squares regression that use the lags of dependent and independent variables. The ARDL model is generally denoted by ARDL (p, q_1,……q_k). Where p represents the lags of the dependent variable, q_1 represent the number of lags of first independent variable and q_k represent the number of k-th independent variable. Some of the independent variables will not bear lags, thus, are known as fixed or static independent variables. The ARDL general is estimated in order to know the properties and lag selection of the model by the ARDL technique. This model carries both the short and long-term estimates of the model and is generally used to check if the model is viable or not.

In our study, the ARDL general model for second objective is as follows:

$$\begin{aligned}\Delta lnCO_{2t} = \beta_0 &+ \sum_{k=1}^{n} \beta_1 \Delta\, lnCO_{2(t-k)} + \sum_{k=0}^{n} \beta_{2k}\, \Delta lnEC_{t-k} + \sum_{k=0}^{n} \beta_{3k}\, \Delta lnGDP_{t-k} \\ &+ \sum_{k=0}^{n} \beta_{4k}\, \Delta lnGDP_{t-k}^2 + \sum_{k=0}^{n} \beta_{5k}\, \Delta lnINVAD_{t-k} \\ &+ \sum_{k=0}^{n} \beta_{6k}\, \Delta lnTrade_{t-k} + \sum_{k=0}^{n} \beta_{7k}\, \Delta lnPop_{t-k} + \varphi_1 lnCO_{2(t-1)} \\ &+ \varphi_2 lnEC_{t-1} + \varphi_3 lnGDP_{t-1} + \varphi_4 lnGDP_{t-1}^2 + \varphi_5 lnINVAD_{t-1} \\ &+ \varphi_6 lnTrade_{t-1} + \varphi_7 lnPop_{t-1} + \epsilon_t \qquad (4.6)\end{aligned}$$

Where β_0 is the drift component in the equation and ϵ_t is the white noise. The error correction dynamics are represented by $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$ and the long-run relationship is shown by $\varphi_1, \varphi_2, \varphi_3, \varphi_4, \varphi_5, \varphi_6 \varphi_7$.

The estimation of the ARDL general is as follows:

Table 4.13: ARDL (1, 0, 2, 2, 1, 1, 1) General Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNCO2(-1)	0.231464	0.095432	2.425436	0.0225
LNEC	0.506202	0.247864	2.042254	0.0514
LNGDPPC	4.899705	4.895817	1.000794	0.3262
LNGDPPC(-1)	-18.10924	7.089253	-2.554464	0.0168
LNGDPPC(-2)	18.12936	7.343189	2.468867	0.0204
LNGDP2	-0.266269	0.273965	-0.971908	0.3401
LNGDP2(-1)	1.065775	0.423924	2.514071	0.0185
LNGDP2(-2)	-1.079666	0.444695	-2.427881	0.0224
LNINDVA	-0.238118	0.205571	-1.158325	0.2573
LNINDVA(-1)	-1.467483	0.093576	-15.68224	0.0000
LNTRADE	0.026491	0.123631	0.214276	0.8320
LNTRADE(-1)	0.566216	0.077804	7.277495	0.0000
LNPOP	-21.80949	2.787454	-7.824161	0.0000
LNPOP(-1)	21.66978	3.001358	7.219990	0.0000
C	-17.94611	10.46648	-1.714626	0.0983
Diagnostic Tests				
R-squared	0.994574	Mean dependent variable		1.335932
Adjusted R-squared	0.991653	S.D. dependent variable		0.570713
S.E. of regression	0.052142	Akaike info criterion		-2.793467
Sum squared residuals	0.070688	Schwarz criterion		-2.166551
Log likelihood	72.26608	Hannan-Quinn criterion		-2.565179
F-statistic	340.4341	Durbin-Watson stat		2.444363
Probability (F-statistic)	0.000000			
*Note: p-values and any subsequent tests do not account for model selection.				

4.3.4 ARDL Long-run Results

The study reveals the presence of a long-run relationship between the variables of the study by conducting Johansen cointegration test and ARDL bounds test. The study further conducts the long-run test under ARDL using the OLS approach to determine the long-run relationship between the variables. The long-run results of the model can be estimated by considering the following equation.

$$lnCO2 = \gamma_0 + \gamma_1 lnEC_t + \gamma_2 lnGDP_t + \gamma_3 lnGDp^2{}_t + \gamma_4 lnINVAD_t + \gamma_5 lnTrade_t + \mu_t \quad (4.7)$$

Where $\gamma_0 = \frac{\alpha_0}{1-\sum \alpha_{1i}}, \gamma_1 = \frac{\alpha_{2i}}{1-\sum \alpha_{1i}}, \gamma_2 = \frac{\alpha_{3i}}{1-\sum \alpha_{1i}}, \gamma_3 = \frac{\alpha_{4i}}{1-\sum \alpha_{1i}}, \gamma_4 = \frac{\alpha_{5i}}{1-\sum \alpha_{1i}}, \gamma_5 = \frac{\alpha_{6i}}{1-\sum \alpha_{1i}}$.

The results of the long-run relationship are presented in Table 4.14. The long-run results reveal that energy consumption in Malaysia has a positive impact on the CO_2 emissions, and the concentration of emissions is increased due to the use of non-renewable energy resources for production and other purposes. The results reveal that if there is an increase of 1% in the use of energy resource, it will cost an increase of 0.65% in the CO_2 emissions. Furthermore, the increasing impact of the energy consumption on the CO_2 emissions is significant, so the increase in the use of non-renewable energy is one of the main sources of environmental pollution and this outcome of the study is similar to the previous studies (Alshehry & Belloumi, 2014; Begum *et al*., 2015; Farhani *et al*., 2014; Farhani & Ozturk, 2015). This outcome of the study is mainly due to the use of non-renewables in the production of electricity and industrial processes which emit a huge amount of CO_2 emissions in the atmosphere. In the long-run, the impact of economic growth on the environmental quality is measured by per capita real GDP, and the results conclude that there is a positive relationship between economic growth and environmental pollution. The result concludes that economic growth is the one of the main sources deteriorating the environmental quality in Malaysia. This result can be supported by some previous studies (Begum *et al.*, 2015; Chandran & Tang, 2013; Farhani & Ozturk, 2015; Saboori *et al.*, 2014). This outcome of the study is mainly because the economic activities in Malaysia are almost 90%

attributed to the use of non-renewable energy resources and the utilization of these energy resources emit an extensive amount of CO_2 in the atmosphere, thus, polluting the environment. The study further reveals that the impact of higher income (GDP^2) is negative on the CO_2 emissions (i.e. environment-friendly) in the long-run. The negative relationship between the squared term of GDP and CO_2 emissions is the essential part of claiming the presence of EKC between economic growth and environmental pollution and is in line with some of the previous work (Al-mulali *et al.*, 2015; Saboori *et al.*, 2012; Shahbaz *et al.*, 2014; Shahbaz, Lean, & Shabbir, 2012).

Table 4.14: ARDL Long-run Results

Regressor	**Coefficient**	**Standard Error**	**Probability**
LnEC	0.658657	0.167742	0.0006***
LnGDPpc	6.401547	2.810016	0.0312**
LnGDP^2	-0.364537	0.161284	0.0324**
LnInvad	-2.219285	0.149486	0.0000***
LnTRADE	0.771216	0.066687	0.0000***
LnPop	-0.181786	0.274129	0.5131
C	-23.351020	13.226568	0.0892

EKC Proof	**$-B_2/2\beta_3$ (-GDP/2GDP^2)**	**Turning point Value**	**LnGDP Highest value**	**Conclusion**
Turning point	-6.401547/2(0.364537)	**8.780380318= US$6505.351**	**9.21680017= US$10064.81**	**EKC validated**

Note: ** represent the level of significance at 10% and 5% respectively

The presence of inverted U-shape relationship between income and carbon dioxide emissions can be calculated by knowing the turning point value of long-run income elasticity on CO_2 emissions. The long-run results of the study show that the income elasticity of the CO_2 emissions is calculated by $-\beta_2/2\beta_3$. Putting the values, we have $-6.4015/2(-0.3645)$ and the outcome of this equation is 8.78. This long-run income elasticity of CO_2 emissions is thus compared with value of $LnGDP_c$. Since this long-run income elasticity of CO_2 emissions is lower than the highest value of $LnGDP_c$, which is US$6505.351. Thus, we can say that there is an inverted U-shaped relationship between income and CO_2 emissions which represent the presence of EKC hypothesis between income and CO_2 emissions in the long-run. The long-run results of this thesis also indicate a negative relationship between structural change in the economy and CO_2 emissions in Malaysia.

The reason for this inverted U-shape relationship between economic growth and CO_2 emissions is the transition from more manufacturing and industrial activities towards more services sector and information based activities. At first the due to the focus on more manufacturing activities the increase in per capita income also leads to an increase in the environmental pollution because more energy-intensive activities were involved in boosting the economic growth of the country. Reaching a peak point of emissions and manufacturing activities the ratio between manufacturing and services sector changed and services sector become more dominant in contributing to the GDP almost half of the share of GDP. The turning point of the EKC curve occurred during the 1996, when the per capita income of the country crossed the threshold value of the turning point of the EKC. The relationship between economic growth and CO_2 after 1996 in Malaysia in this model is environment-friendly as services sector activities lead to an increase in economic growth while keeping the emissions low.

The study also claims that the impact of structural change on the environmental quality is negative which is according to the conclusions of Panayotou (2000). This impact of structural change is negatve and is also significant, meaning that an increase in the industry value added will decrease the environmental pollution as the country moves from more agriculture and manufacturing based economy towards a more services based economy. This finding of the study is in line with the work of previous researchers, including Marsiglio *et al*. (2015) among others. This result of the study is in line with the current state of industrial development of Malaysia as the share of manufacturing value added as percent of GDP decreases from 30.37% of total GDP in 2004 to 23.135 of total GDP in 2012, and the share of services value added increases from 42.19% to 50.07% of total GDP. This increase in the share of services value added

(% of GDP) and a decrease in the share of manufacturing value added (% of GDP) is the reason the structural change in Malaysian economy is environment-friendly. This means that most of the industrial activities in Malaysia are carried out in the services sectors rather than the manufacturing sectors which leads to the less emissions of CO_2 in the atmosphere. This result is because of the composition effect of economic growth, at first the economy moved from agriculture to industrialization on the path of economic growth, thus, increasing the environmental pollution. Moreover, when the balance of economic growth shift towards more information and services-based production the domestic environmental pollution reduced due to changes in the demand and supply side.

Furthermore, the study also arrives at the conclusion that international trade is at the cost of environmental quality. The study reveals that an increase of 1% in trade will further deteriorate the environmental quality by 0.77% in the long-run. The impact of trade openness on the CO_2 emissions is positive and significant, thus, the study claim that openness of trade is responsible for the deteriorating environmental quality in Malaysia and is one of the potential determinants which cause an increase in the concentrations of CO_2 emissions (Farhani *et al*., 2014; Managi *et al*., 2009; Omri *et al*., 2015; Shahbaz & Leitão, 2013; Yunfeng & Laike, 2010). Last but not the least the long-run results of the study reveal that increase in population adds to the environmental pollution. The relationship between population and CO_2 emissions is positive but insignificant. Thus, population growth cannot be considered as the solitary reason for the environmental degradation in Malaysia and this oucome is similar to some previous literature (Begum *et al*., 2015; Onafowora & Owoye, 2014; Wang, Fu, & Zhang, 2015). The link between environmental qulaity and population growth is somewhat divided into two groups where some researchers are of the view that an increase in the popultion is the main reason for environmental pollution because it will lead to higher consumption, income inequality, more industrilization, inappropriate government policies, and inefficient technologies to meet the needs of the growing popultion. On the other hand, researchers are of the view that more people are the key to overcome the environmental pollution by the development of new technologies in abundant amonts. Thus, the population increase cannot be just solely responsible for the environmental degradation, but it can be treated just as a factor among many other factors that adds to the deleterious effects of economic, social and political factors.

4.3.5 ARDL Short-run Results

Knowing the long-run relationship and the impact of regressors of the CO_2 emissions, the study also computed the short-run relationship between the regressors and the dependent variable of the study under the ECM. The short-run results of the model can be estimated under the following equation.

$$\Delta lnCO_{2t} = \alpha_0 + \sum_{k=1}^{n} \alpha_{1k}\,\Delta lnCO_{2(t-k)} + \sum_{k=1}^{n} \alpha_{2k}\,\Delta lnEC_{t-k} + \sum_{k=1}^{n} \alpha_{3k}\,\Delta lnGDP_{t-k} + \sum_{k=1}^{n} \alpha_{4k}\,\Delta lnGDP^{2}_{t-k} + \sum_{k=1}^{n} \alpha_{5k}\,\Delta lnINVAD_{t-k} + \sum_{k}^{n} \alpha_{6k}\,\Delta lnTrade_{t-k} + \theta ECT_{t-1} + \epsilon_t \qquad (4.8)$$

The short-run results of the study reveal that energy consumption has an increasing and significant impact on the carbon dioxide emissions in Malaysia in the short run. The results claim that if there will be an increase of 1% in the energy consumption, it will give rise to the CO_2 emissions by 0.61% in the short-run. This finding of the study is in line with the previous work of (Islam *et al*., 2013; Saboori & Sulaiman, 2013a) for Malaysia among others. The study claims that increase 1% in the economic growth in the short-run will decrease the environmental pollution due to CO_2 emissions by 17.34%. This short-run result is an environment-friendly and this support the work of previous researchers, including (Ozturk & Acaravci, 2013) for Turkey and (Saboori & Sulaiman, 2013a) for Philippine and Indonesia among the five ASEAN countries.

Table 4.15: ARDL Short-run Results

Regressor	Coefficient	Standard Error	T-Ratio	Probability
DLnEC	0.614718	0.131025	4.691618	0.0001
DLnGDPPc	-17.348483	3.769505	-4.602324	0.0001
D(LNGDPPC (-1))	-18.129356	5.423722	-3.342604	0.0025
DLnGDP^2	1.031762	0.221822	4.651307	0.0001
D(LNGDP2(-1))	1.079666	0.444695	2.427881	0.0224
DLnInvad	-0.262871	0.263531	-0.997494	0.3277
DLnTrade	0.041332	0.147570	0.280082	0.7816
DLnPop	-20.700900	2.966092	-6.979183	0.0000
Ecm (-1)	-0.726771	0.102326	-7.102477	0.0000

Note: *, **, and * represent the significance level at 10%, 5%, and 1% respectively**

On the other hand, a higher per capita real GDP (higher economic growth) has a positive and significant impact on the environmental pollution, and it adds to the pollution. A 1% increase in the GDP^2 will lead to an increase of 1.03% in the CO_2 emissions in Malaysia in the short-run. This result is in line with the short-run results of the previous studies, including Saboori & Sulaiman (2013a) for Indonesia and Philippine among five ASEAN countries. Moreover, in the short-run, the structural changes in the economy have a negative, but insignificant impact on the environmental pollution, meaning that an increase of 1% in the industrial value added will lead to a decrease in the CO_2 emissions by 0.26% in the short-run. This result indicates that the betterment of the environment cannot be entirely related to the structural changes in the economy as the impact of the structural changes in the economy on the environment is insignificant.

Furthermore, trade openness deteriorates the quality of the environment in Malaysia in the short-run but its impact is insignificant. This outcome of the study is in line with the work of Managi *et al*. (2009) for non-OECD countries, and Halicioglu (2009) for

Turkey. Furthermore, the impact of the rising population in the short run is deteriorating for the environment, and an increase of 1% in the population will give rise to bout 20% more pollution in the country in the short-run which is very dangerous. The result of the study is in line with the previous work, including Lantz & Feng (2006) for Canada and Zarzoso *et al*. (2007) for European countries. Last but not the least, the error correction term (ECT_{t-1}) is negative and significant at 0.000%, thus, representing the speed of adjustment in the long-run equilibrium. The study claims that if there will be any disequilibrium in the short-run, it will be adjusted back to equilibrium with a speed equal to the value of the error correction term because this ECT_{t-1} represent the speed of adjustment towards the long-run equilibrium. The short-run disequilibrium will be adjusted towards equilibrium in the long-run with a speed of 72% per year. The results of the error correction model are shown in Table 4.15.

4.3.6 Diagnostic Tests

The study also applied diagnostic tests to confirm that there is no problem with the estimation of results, and the model is overall stable. The results show that the value of R^2 is 0.71 which explains that 71% of the variation in the dependent variable (CO_2) due to the changes in regressors of the study, thus, the model is a good fit. The value of the adjusted R^2 is 0.55, and it indicates that model is a good fit as the value of adjusted R^2 is less than that of the R^2 due to the inclusion of more predictors in the model as the addition of predictors affect the value of adjusted R^2. The value of adjusted R^2 increases if the inclusion of a new predictor improves the model above the predicted probability and decreases when the inclusion of new variable improves the model by less than expected by chance. Furthermore, the study focused on the Durbin-Watson statistics to look for the presence autocorrelation problem in the regression. The range of the value of DW-statistics is from 0 to 4, and a value near to 2 is considered free of autocorrelation. The DW-statistics of the current model is 2.41 which is very near to 2, thus, confirms that there is no problem of autocorrelation in the model, which is a good sign for the model. Furthermore, the overall fit of the model is shown by the F-statistics and its probability value. The F-statistics and probability F-statistics values of the model are 4.60 and 0.000, thus, confirming the overall goodness of fit of the model. A small standard error of regression 0.056 also predicts that the deviation from the mean is the small one, which is a good sign for the model. The study also focused on the residual sum of squares (RSS) and concluded that there is a little difference between predicted and actual estimated values. A small value of 0.08 of RSS indicates that the model is a tight fit to the data. The results are presented in Table 4.16.

Table 4.16: Diagnostic Tests

R^2	0.712744	**DW-statistic**	2.41535
Adjusted R^2	0.558068	**S.E. of Regression**	0.05672
F-Statistics (Prob.)	4.6079 (0.0003)	**RSS**	0.08365
Test-Statistics	**LM version**	**F Version**	**Conclusion**
Serial Correlation (Chi SQ)	1.5186(0.4680)	0.5814(0.5651)	**No Serial Correlation**
Functional Form (Chi SQ)	2.6082 (0.0944)	0.93074 (0.344)	**Correct functional Form**
Jarque-Bera (Chi SQ)	0.71780 (0.698)	Not Applicable	**Normally Distributed**
Heteroscedasticity (Chi SQ)	6.2290 (0.6216)	0.7183 (0.6739)	**No Heteroscedasticity**

Moreover, the study also tested the model for the problem of serial correlation, heteroscedasticity, normality and functional form. The study claims that there is no serial correlation problem in the model as the Bruesch Pagan LM serial correlations chi-squared value accepts the null hypothesis of no serial correlation because both LM version and F version chi-squared probability values are greater than 0.05 and we cannot reject the null hypothesis. The study also focused on the problem of heteroscedasticity in the variances of the data set and applied the Breusch-Pagan Godfrey test of heteroscedasticity to detect the presence of heteroscedasticity in the model. The study concluded that there is no problem of heteroscedasticity as the chi-squared value of the Breusch Pagan heteroscedasticity is greater than that of the probability value of 0.05. Thus, the study cannot reject the null hypothesis of homoscedasticity and conclude that there is no problem of heteroscedasticity in the model. The functional form of the model is very necessary to arrive at correct estimates of the test, and the study tested for the functional form of the model and found that the probability value of 0.094 which is greater than 0.05, thus, we accept the null hypothesis that the functional form of the model is correct. The study also checked for the normal distribution of the data and applied the Jarque-Berra test with a null hypothesis of normally distributed data. The JB test concluded that the data is normally distributed as we cannot reject the null hypothesis of normal distribution due to the higher Jarque-Bera value of 0.717, and the probability value of 0.69 is also much higher than that of the threshold value of 0.05. The value of skewness and kurtosis are 0.30 and 2.78 respectively, thus, indicating that the data is normally distributed.

4.3.7 Ramsay's RESET and Omitted Variables Likelihood Ratio Test for Model Specification Errors (Objective 2)

The correct specification of the model is very important to arrive at efficient estimates of the coefficients. The present study also checks the current model for the specification errors in the model to ensure there is no specification problem in the model. The study applied the most common test of regression error specification estimation test, (RESET) presented by Ramsay. This test checks the model for the functional form and omitted variables in the model, if any. The results of the test arrive at the conclusion that there is no problem with the functional form of the model as the F-statistics value and probability values of 2.60 and 0.094 respectively are higher than the threshold value of 0.05. Thus, we cannot reject the functional form of the model, and the study concludes that the functional forms of the study are correct. The test also checked for the omitted variables and checked the square and cubed term of the variables if missing. The results concluded that these terms are insignificant. Thus, there is no problem of omitted variables bias in the model. The results of the tests are presented in Table 4.17.

The study further applied the omitted variables test and concluded that there is no necessary omitted variable left out of the model because the F-statistics value and likelihood ratio value of 0.37 and 0.54 with the probability values of 0.60 and 0.43 cannot reject the null hypothesis that the square and cubes of the fitted values and financial development have significantly zero effect or no significant impact on the dependent variable. The study also noted the significance values of the fitted values and financial development and they also conclude that they are insignificant in affecting the dependent variable. Thus, the study claims that there is no necessary variable omitted from the model that can influence the estimated of the model effectively.

Table 4.17: Ramsay RESET Test for Omitted variables and functional form

F-statistic	**Value**	**Probability**	
	2.608232	0.0944	
Omitted Variable Likelihood Ratio Test	**Value**	**Probability**	
F-statistics	0.374134	0.5463	
Likelihood Ratio	0.609034	0.4352	
Omitted variables	**Coefficient**	**Standard Error**	**Probability**
FITTED^2	1.856937	11.87165	0.8770
FITTED^3	-0.486546	2.556910	0.8507
LnM2	-0.042865	0.023671	0.0822

4.3.8 CUSUM and CUSUMSQ Tests for Model Stability (Objective 2)

The stability of the overall model is fundamental for the correct estimation of the model. The present thesis also checks for the overall stability of the model and applied the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ). Both these test check for the presence of any structural break occurred during the study period. The results indicate that the coefficient of vector β (the disturbance variance) in every period is the same which is the null hypothesis of the test against the alternative hypothesis that vector β is not the same and keep on changing in different periods. The results conclude that both the residual lines are inside the upper and lower lines of confidence intervals at 5%, thus, the model is stable as all the vector β coefficients are the same and hence there is no structural break in the model. The study claims that the regression error of the recursive residuals and their squares both are well inside the significance lines at 5% and the model is stable.

Figure 4.5: Graph of CUSUM and CUSUMSQ Tests

Figure 4.5(a): Graph of CUSUM test

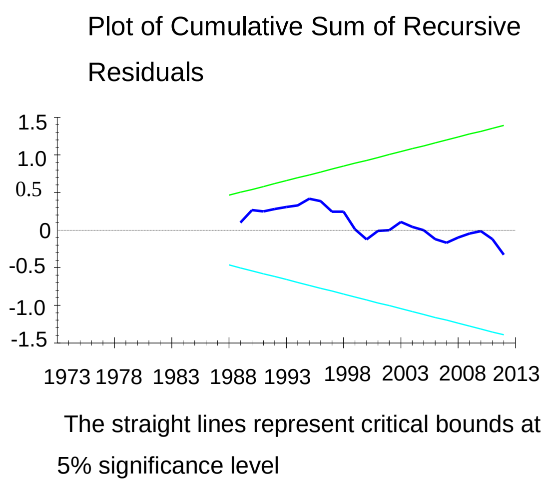
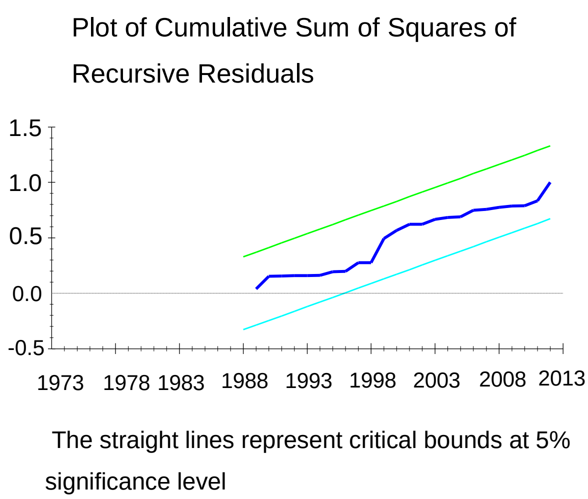


Figure 4.5(b): Graph of CUSUMSQ test



4.4 Objective Three of the Study: To determine the Role of Interest Rate in the Income-Pollution Relationship

Environmental pollution has been the center stage of discussion in the literature from the start of the era of industrialization. The governments and regulatory bodies around the world started looking for the determinants of pollution and they found out that carbon dioxide emissions are one of the major contributors to the environmental pollution. There has been voluminous literature that focused on the macroeconomic, social, globalization and political issues caused by the environmental pollution. Researchers around the globe have also focused on macro and microeconomic determinants of CO_2 emissions, namely economic growth, energy consumption, trade openness, financial development, urbanization, and transportation among others. The literature has been missing an important aspect of the changes in the interest rate that can affect the environmental pollution.

The biggest polluter of air is the transportation sector, electricity consumption, oil, and coal-based generators are polluting the soil, and ocean and waterways are polluted by industrial wastes. The impact of interest rate could be established by looking into the use of capital stock, as there is a potential link between all the pollutions (industrial production, transportation, and other economic activities) and capital stock. There are two types of capital stock, one is the polluting and the other is non-polluting, and the most dominant of these two is the polluting capital. It is argued that changes in the interest rate can affect the pollution by affecting the polluting capital (Rashid & Sharma, 2008). The current study applied the real interest rate to investigate its impact on the environmental pollution in the income-pollution relationship. This study is the first of its kind as other studies have used the cost-benefit analysis and used the discount rates to find out the present value of the future cost of environmental pollution to control its impacts in the future. This study focused the use of real interest rate (market rate) to investigate the impact of variations in the interest rate on the environmental quality by affecting the capital stock which is one of the basic sources of environmental pollution used in the process of production necessary for economic growth and other activities carried out. The changes in the interest rate in a country can affect the pollution level from three aspects i.e. (i) the scale effect, (ii) the composition effect, and (iii) the technique effect (Rashid & Sharma, 2008).

The study also emphasized on the Ramsey-Cass-Koopmans model developed by Ramsey (1928), theoretical framework elaborated by Cass (1965), and Koopmans (1965) to explain the inverse relationship between income and pollutants incorporating the role of interest rate. The study will investigate the role interest rate in the income-pollution relationship to see whether the decrease in the rate of interest with the growth in income can explain the inverse U-shape relationship between economic growth and carbon dioxide emissions in the case of Malaysia. Based on the literature discussions the study hypothesized that:

H_7: Interest Rate can influence the patterns of CO_2 emissions in Malaysia

H_8: EKC relationship between higher per capita income and CO_2 emissions is validated in Malaysia

The study applied the following methodology to investigate these hypotheses and to arrive at a conclusion about the role of interest rate in the environmental scenario.

4.4.1 Unit Root Test Results (Objective 3)

The first step in analyzing the data is to look for the properties of the data if they are ready for estimation or not. To investigate the presence of the unit root in the series the study applied the unit root tests to explore if the variables are stationary for analysis or not. The study used ADF, PP, DF-GLS, and Ng-Perron unit root test to check if the data is stationary or not. The results of all the test show that all the variables have unit roots in their level forms except the real interest rate which is stationary in its level form.

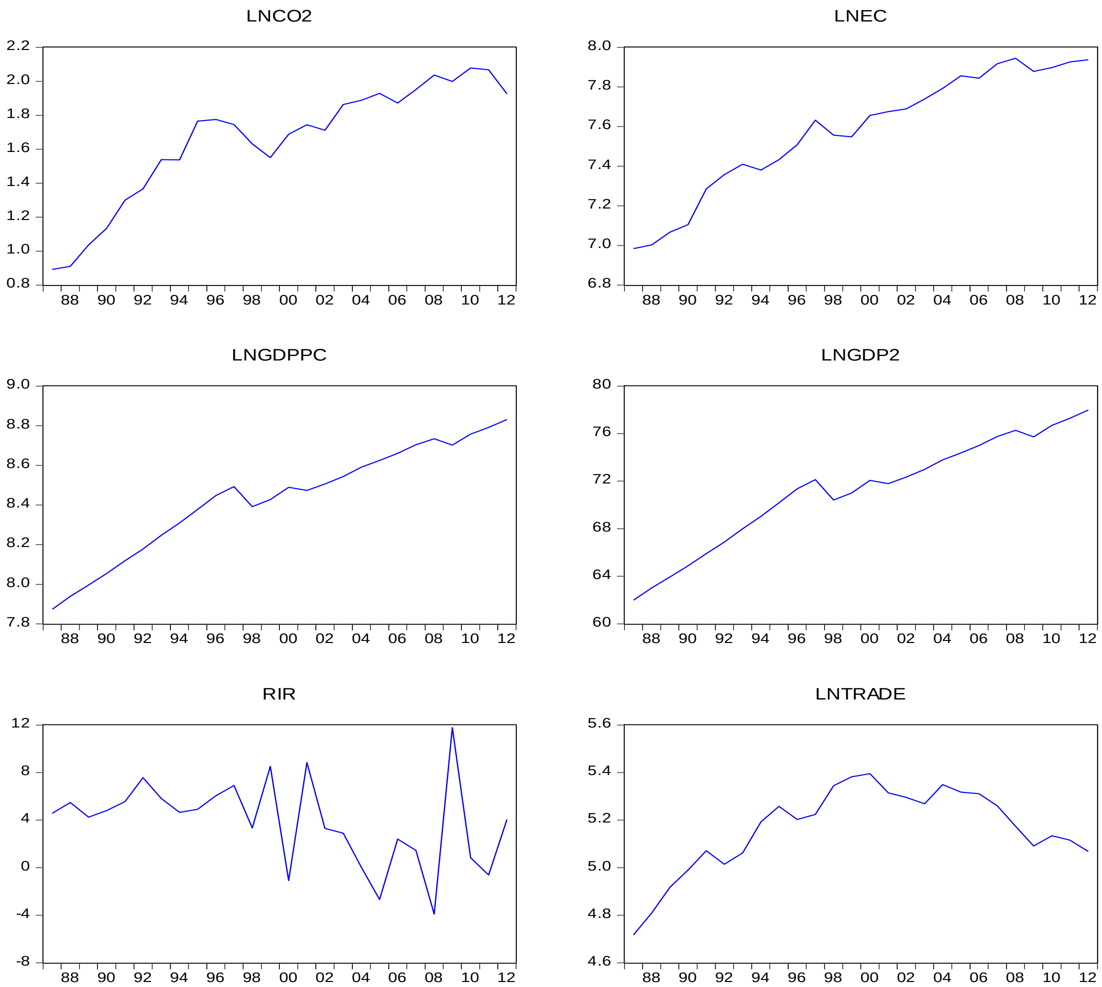
Table 4.18: ADF, PP, and DF-GLS Unit Root Test

Variables	**ADF Level**		**PP level**		**DF-GLS level**	
	Intercept	**Trend and intercept**	**Intercept**	**Trend and Intercept**	**Intercept**	**Trend and Intercept**
$LnCO_2$	-2.487654	-1.508637	-2.556547	-1.508637	-0.996661	-1.581441
LnEC	-1.962131	-1.690451	-2.067373	-1.690451	-0.406998	-1.783908
LnGDP	-2.106114	-2.228331	-2.424354	-2.210685	0.025991	-1.885001
$LnGDP^2$	-1.880666	-2.226962	-2.163162	-2.199470	0.068617	-1.936392
RIR	-5.384***	-6.6588***	-5.368***	-6.658***	-5.474***	-6.8074***
LnTrade	-0.922995	-0.417801	-2.907743	-1.452378	-1.545098	-1.206904
1st Difference	**Intercept**	**Trend and Intercept**	**Intercept**	**Trend and Intercept**	**Intercept**	**Trend and Intercept**
$LnCO_2$	-4.119***	-4.905***	-4.122***	-4.905***	-4.051***	-5.070***
LnEC	-3.9763**	-5.0593***	-4.796***	-5.399***	-3.975***	-5.015***
LnGDP	-4.369***	-4.6137***	-4.350***	-4.603***	-4.291***	-4.829***
$LnGDP^2$	-4.479***	-4.6580***	-4.468***	-4.653***	-4.433***	-4.875***
LnTrade	-3.3805**	-5.4226***	-3.227***	-7.241***	-3.233629	-5.597***

The results concluded that test statistics values of the ADF, PP, and DF-GLS are less than the critical values of the test at all the significance levels, namely 1%, 5%, and

10% in their level form, thus, concluding the presence of a unit root in the series. The results of the unit root tests are shown in Table 4.18. The study concluded that the test-statistics value of the three tests in the case of real interest rate is greater than the critical values of the test at all the significance level, thus, concluding that there is not unit root in the series in its level form and is stationary. The study also checks the series at the level form graphically and concluded that all the series have unit roots as they have some trend in them. The study also concluded that real interest rate is stationary in its level form as the graph shows there is no trend in the series. The graphs of the series are shown in Fig. 4.6.

Figure 4.6: Graphs of the Series in their Level Form



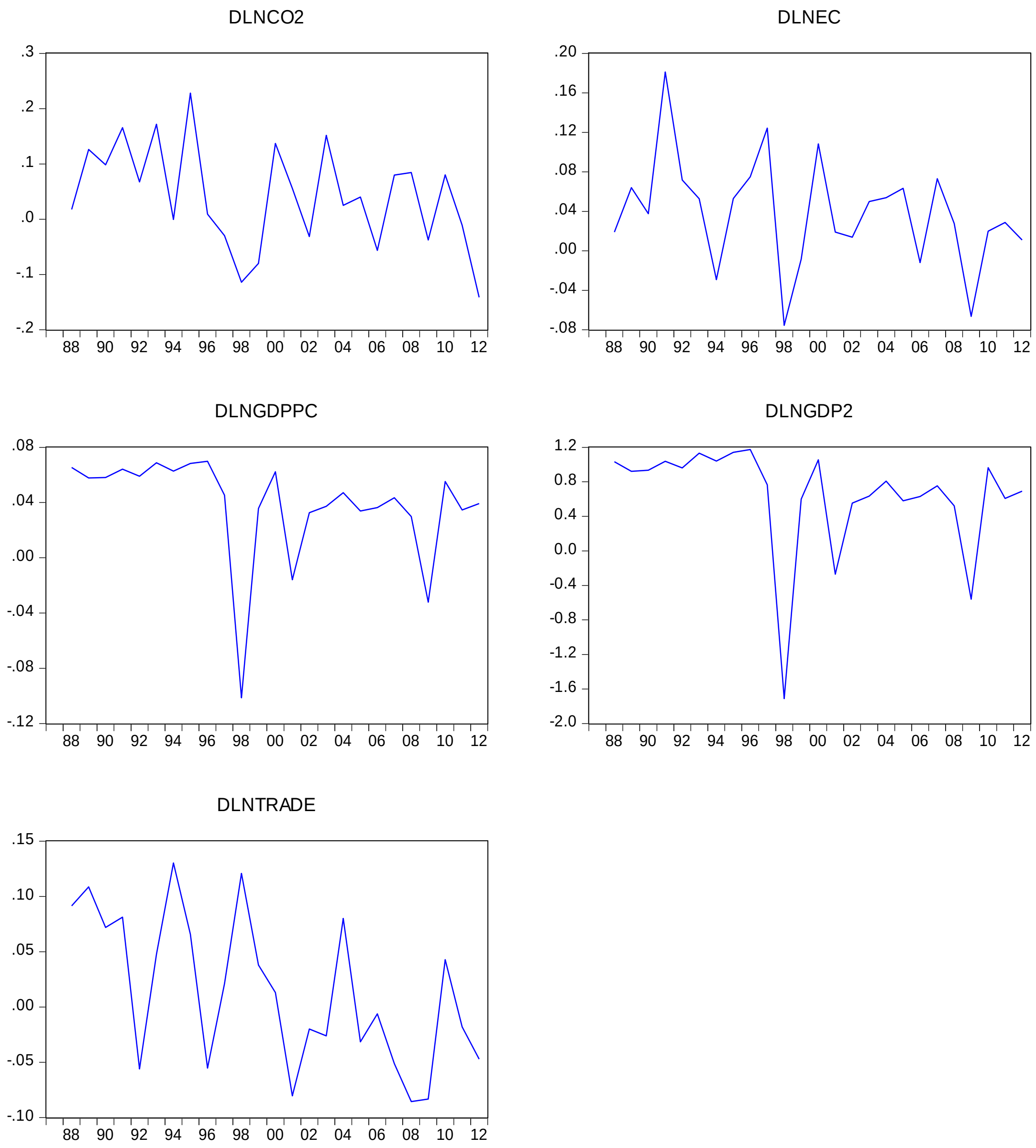
The study further applied the Ng-Perron unit root on all the variables and concluded that all the variables are non-stationary at their level form as the test statistics value of MZ_a, MZ_t, and MSB are less than the critical values of the tests at all levels of significance except for the real interest rate. The study further applied the unit root test to the series in their difference form and concluded that all the remaining non-stationary variables are stationary at first differences. The study also shows that the variables have no unit root in their differenced form as the graphs of the data have no trend in the data, so they are stationary. The results of the series are shown in Fig. 4.7. The results of all the unit root tests show that test statistics values of ADF, PP, DF-GLS, MZ_a, MZ_t, and MSB are greater than the critical values of the test at some level of significance in their differenced form.

Table 4.19: NG-Perron Unit Root Test Results

Variables	NG-Perron Level Intercept				NG-Perron Trend and Intercept			
	MZ_a	MZ_t	MSB	MPT	MZ_a	MZ_t	MSB	MPT
$LnCO_2$	-0.1274	-0.0995	0.7813	35.598	-3.57010	-1.1126	0.3116	21.975
LnEC	0.6357	0.6109	0.9610	59.888	-4.724***	-1.35***	0.2876	18.12***
LnGDP	1.2325	1.2966	1.0519	79.317	-3.46667	-1.2717	0.3668	25.460
$LnGDP^2$	1.2834	1.3433	1.0466	79.332	-3.88749	-1.3607	0.3500	22.990
RIR	-12.337	-2.4836	0.2013	1.9858	-39.6091	-4.4393	0.1120	2.3577
LnTrade	-2.0808	-1.018	0.4892	11.755	-8.14837	-1.8697	0.2294	11.574
1st Diff.	Intercept				Trend and Intercept			
$LnCO_2$	-11.873**	-2.27**	0.192*	2.642*	-17.209**	-2.85**	0.1657*	5.761*
LnEC	-18.45***	-3.03***	0.1642	1.34***	-25.306**	-3.55**	0.1405	3.601
LnGDP	-11.70**	-2.41**	0.206*	2.098*	-16.874*	-2.893*	0.171**	5.467**
$LnGDP^2$	-11.8159	-2.4303	0.2056	2.0746	-11.9804	-2.4342	0.2031	7.6741
LnTrade	-8.381	-1.9734	0.2354	3.1915	-27.2024	-3.6877	0.13557	3.35124

The graphs of the series at their first differences are given in Fig. 4.7. All the graphs of the series show that the series are stationary at their first differences and there is no clear trend in any of the series. Thus, these graphs confirmed the results of the above unit root tests.

Figure 4.7: Graphs of Series at First Differenced form



4.4.2 ARDL General

The ARDL model is generally denoted by ARDL (p, q_1,……q_k). Where p represents the lags of the dependent variable, q_1 represent the number of lags of first independent variable and q_k represent the number of k-th independent variable. Some of the independent variables will not bear lags, thus, are known as fixed or static independent variables. The general ARDL model for objective is as follows:

$$\Delta lnCO_{2t} = \beta_0 + \sum_{k=1}^{n} \beta_1 \Delta\, lnCO_{2(t-k)} + \sum_{k=0}^{n} \beta_{2k}\, \Delta lnEC_{t-k} + \sum_{k=0}^{n} \beta_{3k}\, \Delta lnGDP_{t-k}$$
$$+ \sum_{k=0}^{n} \beta_{4k}\, \Delta lnGDP_{t-k}^{2} + \sum_{k=0}^{n} \beta_{5k}\, \Delta RIR_{t-k} + \sum_{k=0}^{n} \beta_{6k}\, \Delta lnTrade_{t-k}$$
$$+ \varphi_1 lnCO_{2(t-1)} + \varphi_2 lnEC_{t-1} + \varphi_3 lnGDP_{t-1} + \varphi_4 lnGDP_{t-1}^{2}$$
$$+ \varphi_5 RIR_{t-1} + \varphi_6 lnTrade_{t-1} + \epsilon_t \qquad (4.10)$$

Where β_0 is the drift component in the equation and ϵ_t is the white noise. The error correction dynamics are represented by $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ and the long-run relationship is shown by $\varphi_1, \varphi_2, \varphi_3, \varphi_4, \varphi_5, \varphi_6$. The estimation of ARDL general is as follows:

Table 4.20: ARDL (1,0,2,0,1,1) General Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNCO2(-1)	0.054660	0.182511	0.299490	0.7690
LNEC	-0.050469	0.298239	-0.169222	0.8680
LNGDPPC	11.89376	5.755228	2.066601	0.0578
LNGDP PC(-1)	0.744471	0.377320	1.973049	0.0686
LNGDPPC(-2)	-0.836927	0.124155	-6.740987	0.0000
LNGDP2	-0.592240	0.316137	-1.873363	0.0820
RIR	0.004116	0.001576	2.612484	0.0205
RIR(-1)	0.005333	0.002860	1.864898	0.0833
LNTRADE	0.029393	0.059327	0.495439	0.6280
LNTRADE(-1)	-0.092199	0.048130	-1.915614	0.0761
C	-55.53367	26.68886	-2.080781	0.0563
Diagnostic Tests				
R-squared	0.982100	Mean dependent var	1.738966	
Adjusted R-squared	0.969315	S.D. dependent var	0.300041	
S.E. of regression	0.052559	Akaike info criterion	-2.753583	
Sum squared resid	0.038674	Schwarz criterion	-2.217277	
Log likelihood	45.41978	Hannan-Quinn criter.	-2.604834	
F-statistic	76.81317	Durbin-Watson stat	2.474203	
Prob(F-statistic)	0.000000			
*Note: p-values and any subsequent tests do not account for model selection.				

4.4.3 ARDL Cointegration Test Results (Objective 3)

The second step in the regression estimation is to investigate if there is any long-run relationship between the variables of the study. There are two types of tests, namely the Johansen cointegration test and the autoregressive distributed lagged (ARDL) bound testing approach to explore the presence of long-run cointegration between the variables of the model. The study applied only the ARDL bound test of cointegration because the variables of the study are integrated of mixed order i.e. I (0) and I (1), and the Johansen cointegration test cannot be applied, as it is applicable only when the variables are integrated of order I (1). The ARDL bounds test compares the F-statistics value of the bounds test to the upper and lower critical bound values of the test. The idea behind the test is if the F-statistics value of the test is above the upper bound value, the test concludes the presence of a long-run relationship between the variables of the study. The current study applied the bounds test and concluded that there is a long-run relationship present between the variables of the study as the F-statistics value of 3.56 is greater than the upper bound value of 3.35 under the 10% significance level. The study further applied this technique to all the models by making each regressor as dependent variables and found that all the models have a long-run relationship except the one where energy consumption is the dependent variable. Results are depicted in Table 4.21.

Table 4.21: The ARDL Results of Cointegration

Model	**ARDL (2 lag SIC)**	**F-statistics**	**ECT_{t-1} (t-stat)**	**Conclusion**
$LnCO_2$ / lnEC LnGDPpc $LnGDP^2$ RIR LnTrade	(1 0 2 0 1 1)	3.5611*	-0.9453 (0.000) ***	Cointegration
Critical values	**Upper Bound**		**Lower Bound**	
1% level of significance	3.41		4.68	
5% level of Significance	2.62		3.79	
10% level of significance	2.26		3.35	

The study also applied an alternative technique to reach the conclusion of the presence of the long-run relationship between the variables. The study observed the values of the error correction terms ($ECTs_{t-1}$) of all the models and concluded that there is a long-run relationship running between the variables as the error correction terms bear negative and significant value. The study thus validated the presence of a long-run relationship between the variables under ARDL bounds test and error correction mechanism.

4.4.4 ARDL Long-run Results (Objective 3)

The ARDL bounds test of cointegration and ECM test show the presence of a long-run relationship between the variables. The study further investigated the model for the estimation of long and short-run coefficients of the variables. The long-run results of the study can be estimated under the following equation.

$$lnCO2 = \gamma_0 + \gamma_1 lnEC_t + \gamma_2 lnGDP_t + \gamma_3 lnGDp^2{}_t + \gamma_4 RIR_t + \gamma_5 lnTrade_t + \mu_t \quad (4.11)$$

Where $\gamma_0 = \frac{\alpha_0}{1-\sum\alpha_{1i}}, \gamma_1 = \frac{\alpha_{2i}}{1-\sum\alpha_{1i}}, \gamma_2 = \frac{\alpha_{3i}}{1-\sum\alpha_{1i}}, \gamma_3 = \frac{\alpha_{4i}}{1-\sum\alpha_{1i}}, \gamma_4 = \frac{\alpha_{5i}}{1-\sum\alpha_{1i}}, \gamma_5 = \frac{\alpha_{6i}}{1-\sum\alpha_{1i}}$.

The long-run results of the study claimed that energy consumption has no significant increasing impact on the environmental pollution, as the coefficient of the energy consumption is positive but insignificant. The study concluded that in the case of Malaysia energy consumption is not the soul source leading to pollution. The result of the study is similar to previous work of (Ali et al., 2016) for Malaysia. this outcome of the study is also in line with the current energy efficiency measures adopted by Malaysia in the shape of five-fuel diversification policy and other renewable and green technology. The economic growth of the country is also polluting the environment in Malaysia and this outcome is very common as the country is dependent on the non-renewable energy resources for productive purposes. This outcome of the study is in line with the previous work of Ali et al. (2016) and Begum et al. (2015) in Malaysia.

The current model of study mainly emphasized on the role of real interest rate and its relationship with the environmental pollution. The study observed that the coefficient of the real rate of interest is positive and significant, meaning that the current real interest rate in Malaysia is helping the polluting industries and manufacturers to let then polluting the environment. The study concluded that if there will be a 1% increase in the real interest rate in the economy, it can lead to a little increase of 0.009% in the CO_2 emissions, thus, further deteriorating the environmental quality. The study results are similar to the one predicted in the literature and are similar to the Ramsey-Cass-Koopmans model where they concluded that higher real interest rates can harm the environment and lower interest rate is in the favor of better environmental quality when the income of the country is higher. This outcome can be justified as the real interest rate of the country has been fluctuating in the range of -3.90% at lowest in 2008 during the Asian financial crises to force the the business and investors to spend more money to cover the crise. On the other hand, the country has also observed the interest rate with a highest value at 11.78% after the Asian Financial Crises to assess to focus more on the saving and recovery of the foreign reserves. Thus, the real interest rate in the county has fluctuated, thus, the discount rate is sometimes higher and lower than the real interest rate.

Table 4.22: ARDL Long-run Results

Regressor	**Coefficient**	**Standard Error**	**T-stat**	**Probability**
LNEC	0.053387	0.309490	0.172499	0.8655
LNGDPPC	12.483662	4.505891	2.770520	0.0150
LNGDP2	-0.626484	0.232887	-2.690071	0.0176
RIR	0.009995	0.004193	2.383842	0.0318
LNTRADE	-0.066437	0.103791	-0.640103	0.5324
C	-58.744663	18.625318	-3.154022	0.0070
EKC Proof	**$-B_2/2\beta_3$**	**Value**	**LnGDP Highest value**	**Conclusion**
Turning point	-12.48/2(-0.62)	9.96= US$ 21162.8	9.21680017= US$10064.81	**EKC Not validated**

Under the Ramsey-Cass-Koopmans model, since on the average real interest rate is higher than the inter-bank discount rate of the country, thus, environmental quality cannot be improved while the income is increasing. This outcome may undeniably support that there is a positive relationship between the stock of pollution and rate of interest. In other words, the stock of pollution increases when there is only a limited amount of capital available for investments in the country, as most of the money is saved to enjoy the high rate of interest. On the other hand, the country would only be able to bag more labor effort in the green industry when the interest rate or marginal rate of return on capital is decreased to a level when it's below the discount rate. Since the discount rate in the country is at 2.61% and the real interest rate in the country is above the discount rate so the interest rate in the country will lead to more pollution. The results of the ARDL long-run are presented in Table 4.22.

The relationship between the higher economic growth and CO_2 emissions is negative, suggesting that when the per capita income of an economy is high, the people will be more environmentally conscious and will invest more in the environment-friendly projects and technology. The negative sign of the coefficient of GDP2 is the indication of the inverse relationship between economic growth and environmental pollution and thus the EKC hypothesis. Furthermore, the study investigated the presence of the EKC relationship between higher per capita income and CO_2 emissions as the threshold value of the turning point is US$ 21162.8, which fall outside the per capita income elasticity of Malaysia in the logarithmic form and is greater than US$10064.81, the highest value of GDP. Thus, the EKC hypothesis cannot be supported by the inclusion of interest rate in the equation, as the interest rate fluctuations can alter the investments and income level, thus causing changes in the pollution level but its role is not environment-friendly. This outcome of the study can be justified as according to the Ramsey-Cass-Koopmans model, the interest rate can alter the relationship between income and pollution and the pollution will start falling when the real interest rate is lower than the discount rate prevailing in the country. Since, in the case of Malaysia, the real interest rate has been fluctuating and has remained above and below the discount rate in the country, thus the negative relationship between higher income and pollution is valid at the time when the interest rate is lower than the discount rate. The curve between higher income and pollution may be N-shaped as the interest rate is greater than the discount rate before 2002 and becomes lower than the discount rate in the period 2003 to 2008, and then again rose quickly after the 2007-08 economic crises and surpassed the discount rate of the country which is 2.61. The study, thus, did not validate the presence of EKC hypothesis in the presence of interest rate and this result is supported by the turning point of the income-pollution curve. This outcome of the study is negating the the Rybczynksi theorem which postulates that a decrease in the interest rate (lower interest rate) can lead to more investment in the capital-intensive firms and there will be a shift of labor from labor intensive firms towards capital intensive industries, so more capital-intensive industries will be developed in comparison to labor-intensive industries. While on the other hand, high interest rate will not allow the investors to invest in capital-intensive industries, thus there will be more labor-intensive industries and less pollution.

The study further observed the impact of trade openness on the environmental quality, and concluded that trade openness has no significant impact on the environmental quality as international trade cannot decrease the concentrations of CO_2 emissions in Malaysia. It is argued that openness to the international trade leads to an increase in the per capita income and production via the technique effect and scale effect (Antweiler et al., 2001). These effects can also be known as trade-induced technique effect and trade-induced scale effect. The study concluded that trade openness has no significant impact on the environmental quality. Thus, we can say that technique effect effect and scale effect of trade can cancel out the effect of each other in the long-run, thus, leaving no significant impact on environmental quality. The results concluded that the concentrations of carbon emissions increase with an increase in the GDP via the positive scale effect, the pollution decreases with the rise in the per capita income (higher) via the negative technique effect, and also an increase in the openness of trade can decrease the environmental pollution (CO_2 emissions) via the negative composition effect.

4.4.5 ARDL Short-run Results (Objective 3)

The study also applied the error correction mechanism to arrive at the short-run results of the study. The error correction model of the short-run estimates is as follows:

$$\Delta lnCO_{2t} = \alpha_0 + \sum_{k=1}^{n} \alpha_{1k}\, \Delta lnCO_{2(t-k)} + \sum_{k=1}^{n} \alpha_{2k}\, \Delta lnEC_{t-k} + \sum_{k=1}^{n} \alpha_{3k}\, \Delta lnGDP_{t-k} + \sum_{k=1}^{n} \alpha_{4k}\, \Delta lnGDP_{t-k}^{2} + \sum_{k=1}^{n} \alpha_{5k}\, \Delta RIR_{t-k} + \sum_{k}^{n} \alpha_{6k}\, \Delta lnTrade_{t-k} + \theta ECT_{t-1} + \epsilon_t \quad (4.12)$$

Similar to the long-run, the short-run results concluded that energy consumption could not deteriorate the environmental quality as the coefficient bears a positive but insignificant sign in the short-run in Malaysia (Begum et al., 2015; Saboori & Sulaiman, 2013b) . The short-run results concluded that real interest rate even in the short-run increase the environmental pollution as the coefficient of interest rate bears a positive and significant value of 0.004. This outcome may be because the overnight rate of return which is an interest rate on the short-run loans are also above the discount rate prevailing in the country, thus according to Ramsay-Cass-Koopmans model, interest rate in the country will lead to an increase in the environmental pollution. Thus, an increase of 1% in the interest rate will increase the CO_2 emissions by 0.004% in the short-run.

Table 4.23: ARDL Short-run Results

Regressor	**Coefficient**	**Standard Error**	**T-Ratio**	**Probability**
D(LNEC)	0.050469	0.298254	-0.169213	0.8680
D(LNGDPPC)	11.893758	5.756465	2.066156	0.0578*
D(LNGDPPC(-1))	0.836927	0.124155	6.740987	0.0000
D(LNGDP2)	-0.592240	0.316204	-1.872966	0.0821*
D(RIR)	0.004116	0.001576	2.612454	0.0205**
D(LNTRADE)	0.029393	0.059328	0.495436	0.6280
CointEq (-1)	-0.945340	0.182539	-5.178831	0.0001***
EKC Proof	**$B_2/2\beta_3$**	**Value**	**LnGDP Highest value**	**Conclusion**
Turning point	11.89/2 (-0.59)	10.041= US$22948.32	9.21= US$10064.81	**EKC Not validated**
Note: *,,*** represent significance at 10%, 5% and 1% respectively**				

The economic growth bears the expected signs as an increase in the rate of economic growth will bring more pollution in the atmosphere, thus, is at the cost of environmental quality. this outcome may be supported as most of the economic activities in the country are energy-intensive and are emitting huge amount of CO_2 emissions in the atmosphere. However, the higher per capita income reduced the environmental pollution by reducing the CO_2 emissions as the squared term of GDP bears a negative and significant value of -0.592 indicating that an increase in the higher rate of economic growth by 1% will result in the reduction of CO_2 emissions by -0.592% even in the short-run. The study further concluded that EKC hypothesis is not validated even in the short-run in this case as the threshold value of the turning point fall outside the range of the value of per capita income in logarithmic form. The impact of trade openness in the short-run is positive and significant, concluding that an increase in the openness of trade will deteriorate the environmental quality. This may be because of the more polluting imports, producing and exporting the polluting products by utilizing the non-renewable energy resources. The composition effect of international trade is also applicable in the short-run to increase the carbon emissions in the atmosphere. This increase in the emissions both in the short and long-run due to an increase in the openness of trade may be due to the domination of the positive trade-induced scale-technique effect over the negative trade-induced composition effect. Short-run results of the ARDL test are presented in Table 4.23.

4.4.6 Diagnostic Tests Results (Objective 3)

The study applied the diagnostic test to diagnose the model if there is any problem in the model. The study noted a value of 0.85 of the R-square indicating that 85% of the variations in the dependent variable are due to the changes in the independent variables. The results concluded that the model is a good fit as the regressors of the model are responsible for most of the variation in the dependent variables. The study concluded that the model is a good fit as the adjusted R-squared value is 0.64% indicating that 64% of the variations in the dependent variable is due to the changes in the independent variables. The study further investigated the model for the presence of autocorrelation and concluded that there is no autocorrelations problem in the model as the Durbin

Watsons statistics value is near to 2 and is in the acceptable range. The study also observed the residual sum of squares and standard error of regression and noted to have small values indicating the goodness of fit of the model. The overall goodness of fit of the model was checked looking into the value of the F-statistics and its probability value. The test indicated that the model is a good fit as the probability F-statistics value is well below the 0.05% significance. Moreover, the study diagnosed the models by applying the LM serial correlation test of Breusch-Pagan Godfrey to investigate the presence or absence of the serial correlations between the variables of the study. The results indicated that there is no problem of serial correlation as the probability value of the observed chi-square value of 0.344 is well above the 5% level of significance thus accepting the null hypothesis of no serial correlation between the variables.

Table 4.24: Diagnostic Tests

R^2	0.851037	**DW-statistic**	2.282519
Adjusted R^2	0.642488	**S.E. of Regression**	0.050931
F-Statistics (Prob.)	4.080 (0.015)	**RSS**	0.025940
Test-Statistics	**LM version**	**F Version**	**Conclusion**
Serial Correlation (Chi SQ)	2.1305 (0.3446)	0.6694 (0.5267)	**No Serial Correlation**
Functional Form (Chi SQ)	2.261 (0.133)	0.5271 (0.6095)	**Correct functional Form**
Jarque-Bera (Chi SQ)	1.3088 (0.519)	Not Applicable	**Normally Distributed**
Heteroscedasticity (Chi SQ)	10.532 (0.229)	1.4469 (0.2476)	**No Heteroscedasticity**

The study further checks the viability of the functional form of the model and concluded that the functional form of the model is the correct one as the probability value of the test is higher than the rejection level at 5%. The study applied the Jarque-Bera test of the normal distribution to investigate the distribution of the residuals in the model. The results indicated that the residuals in the model are normally distributed and there is no problem with the normality of the data and this is a good sign for the viability of the model. Last but not the least, the heteroscedasticity problem of the variances in the model was also diagnosed by applying the Breusch-Pagan Godfrey test. The test results indicated that the model is free from the problem of heteroscedasticity and the variances of the residuals are equally distributed with same spread. The probability value of the observed chi-square value of 0.229 is higher than the rejection level at 5% level of significance thus we accept the null hypothesis that the variance in the model is homoscedastic. In short, all the diagnostic tests show that the model is a good fit and viable for estimation and the estimates of the model are efficient.

4.4.7 Ramsey's RESET and Omitted Variables Likelihood Test Results (Objective 3)

Aside from the above diagnostic tests for the model validity, the study also investigated the functional form of the model by applying Ramsey's regression error specification estimation test (RESET). The RESET test applies two types of tests, one for the functional form of the model and the other is used to look for any necessarily omitted variables. The results of the test concluded that the functional form of the model is correct as the probability F-statistics value of 0.609 is well above the threshold value of probability for the rejection of the null hypothesis at the 5% level of significance. The study thus accepts the null hypothesis of the correct functional form of the model. The test also investigated the presence of any omitted variables by checking the squares and cubes of the fitted values and concluded that the squares and cubes of the fitted values are not the necessary variables that are left out of the model because probability values of the variables show that they have no significant impact on the dependent variable of the model. The probability values of these variables are high enough for the rejection level of the null hypothesis, indicating that these variables are significantly zero and have no impact on the dependent variable.

The study further applied the omitted variable likelihood ratio test and concluded that financial development is not a necessary variable to be included in the model. The study used the financial development as the necessary variable left out of the model, but the test results concluded that the probability value of 0.71 and 0.52 of the F-statistics test and likelihood ratio test respectively are high enough to reject the null hypothesis that financial development is significantly zero and has no significant impact on the dependent variable. The study accepted the null hypothesis of significant zero impact. The study further concluded that the suspected variable of financial development has no significant impact on the dependent variable CO_2 emission as the probability value is 0.97 and is well above the 5% level of significance.

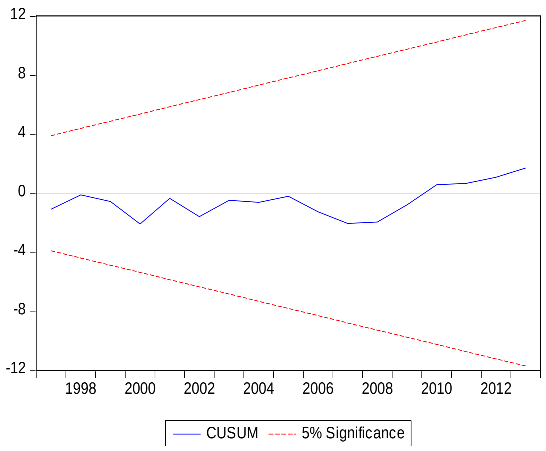
Table 4.25: Ramsay RESET and Omitted Variables Likelihood Ratio Test Results

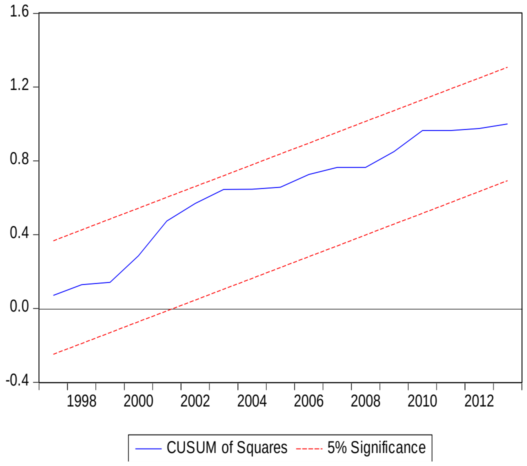
Functional Form			
F-statistic	**Value**	**Probability**	
	0.527145	0.6095	
Omitted Variable Likelihood Ratio Test	**Value**	**Probability**	
F-statistics	0.145311	0.7119	
Likelihood Ratio	0.400418	0.5269	
Omitted variables	**Coefficient**	**Standard Error**	**Probability**
FITTED^2	-2.572094	4.174758	0.5549
FITTED^3	0.509838	1.008959	0.6270
LnM2	0.072570	0.190375	0.9773

4.4.8 CUSUM and CUSUMSQ Test Results (Objective 5)

The study further applied the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of recursive squares of residuals (CUSUMSQ) to check the stability of the parameters of the model. The study applied the CUSUM test to check the cumulative sum of recursive residual errors if they are about the zero line. The study applied two standard errors at the 5% level of significance and the idea behind the test is if the residual errors are inside the critical line, the model parameters will be stable. The CUSUM test concluded that the sum of residual errors falls inside the standard error lines at the 5% level of significance. Thus, the study concluded that the parameters of the model are stable. The study also applied the CUSUMSQ and concluded that the squares of the recursive errors also fall inside the two critical lines at the 5% level of significance and the model parameters are stable. Thus, the study concluded that the model is stable and the estimates of the model are efficient. The plots of CUSUM and CUSUMSQ are shown in Fig. 4.8.

Figure 4.8: Graph of CUSUM and CUSUMSQ Test





4.5 Summary of the Chapter

This chapter of the study investigated the long-run and causal relationship between the variables of the study under different models in different periods of time. The study analyzed the secondary time series data on different variables. The study focused on the impact of structural changes in the economy, technological innovations, the rate of interest on the environmental quality in Malaysia. The study collected the data from World Development Indicators (WDI) 2016, British Petroleum (BP), Department of Statistics Malaysia (DOSM), and Index Mundi Malaysia. The study utilized the Eviews and Microfit software to build the models and run the regression. The study applied different unit root tests to investigate the stationarity level of the series. The study applied the ARDL bounds testing approaches and Johanson cointegration test to examine the presence of the long run relationship between the variables in all the models. Both the tests in different models asserted the presence of a long-run relationship between the variables. The ARDL bounding approach gives the estimates of the model both in the short and long-run. The study applied the Error correction mechanism to come up with the short-run results of the model. Last but not the least the study also applied the Robust least square method to arrive at more robust estimates.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The current chapter is to discuss and conclude the proceeding chapters and the main findings of the study. Section 5.2 summarizes the whole study based on the findings of the objectives and conclusions of the hypotheses. Section 5.3 depicts the contribution of the current study towards literature and methodology. Section 5.4 deals with theoretical and practical implications of the study based on the conclusions of the study. Furthermore, some suggestions and recommendations to the government, regulatory bodies, policy makers, environmentalists, future researchers, and other interested parties are also mentioned. Moreover, section 5.5 implicates the limitations of the study and recommend some future work to be carried out in the same field. The chapter is organized as follows.

5.2 Summary of the Study

One of the common concerns of the governments around the world is to achieve higher and sustainable economic growth with low resource usage intensity and without endangering the future generations' quality of life. This objective of the governments around the world is impaired by the environmental degradation, global warming, and climate change. Thus, the understanding and prediction of the changes in the quality of the environment due to the continuous rise in the economic activities become a pressing issue for the government regulatory bodies and environmental policy makers around the globe. The developing or emerging economies of the world face the problem of conflicting policy choices to continue rapid economic growth, significant resource consumption, and to reduce environmental degradation (Apergis & Payne, 2010). Malaysia, a transition economy, is highly dependent on the non-renewable energy resources to cope with the demand of the expanding population and spreading economic activities. The demand for energy consumption increases with an increase in the industrialization process and in particular with the increasing demand for the electricity. The imbalance ratio between economic growth and demand for energy consumption indicated that the activities driving the growth are energy-intensive. Thus, economic growth in the country is at the cost of environmental quality. It is argued that economic growth increases the environmental pollution in the beginning, but reaching a higher point of income the further increase in the per capita income decreases the environmental pollution, thus, supporting the EKC hypothesis (Ali et al., 2016; Saboori & Sulaiman, 2013). On the other hand, energy consumption has been considered one of the main culprits in polluting the environmental quality in Malaysia (Ali et al., 2016; Begum et al., 2015; Saboori et al., 2014). Other studies focused on some other potential determinants of carbon emissions like financial development (Mahdi Ziaei, 2015; Shahbaz et al., 2013; Tamazian & Bhaskara Rao, 2010; Tamazian et al., 2009). Other researchers focused on the trade openness (Lau et al., 2014; Omri et al., 2015; Rahman, 2013; Shahbaz et al., 2013). On the other hand, some researchers investigated the importance of population growth and urbanization (Begum et al., 2015; Liddle, 2014; Martínez-Zarzoso et al., 2007; Poumanyvong & Kaneko, 2010). Similarly, foreign direct investment is considered an important determinant of the CO_2 emissions (Chandran & Tang, 2013; Omri et al., 2014; Pao & Tsai, 2011). The current study further focused on some new variables that are rarely investigated against CO_2 emissions, including structural changes in the economy, the real interest rate, and technological innovation.

The study collected the annual time series data on all the variables in different time frames for different models. The study collected the data from World Development Indicators (WDI), Department of Statistics Malaysia (DOSM), British Petroleum (BP), and Index Mundi Malaysia. The study collected the data starting from 1971 until 2013 as this is the longest period available on all the variables. The study devised the following objectives to arrive at the conclusion of the study.

5.2.1 Findings and Conclusions of the First Objective

The first objective of the study investigated the role of technological innovation alongside energy use, per capita GDP, and openness to trade. The study emphasized the importance of advancement in technology for the environmental betterment and estimated the short and long-run coefficients of the model. The bounds test revealed the long-run cointegration in the model. The results of the research concluded that technological innovation (patent applications) in Malaysia can enhance the quality of environment as the coefficient of the patent applications is negative in the long-run. The study further concluded that economic growth is at the cost of environmental quality in the long-run while higher per capita income improves the environmental quality which is an indication of the environmental Kuznets curve (EKC) hypothesis. The study concluded that the threshold value of the turning point of the inverted U-shape EKC curve falls within the range of the highest value of the current per capita real income in Malaysia. The study, thus, validated the presence of EKC hypothesis between per capita GDP and carbon emissions in the presence of technological innovation. The study further observed the bidirectional causal relationship between per capita GDP and carbon emissions, technological innovation and carbon emissions, and technological innovations and per capita GDP in the long-run. The causality result shows that there is a feedback relationship between technological innovation and carbon emissions meaning that they can affect each other. This can be justified as the more advanced, less polluting and environment-friendly technology can reduce the carbon emissions while on the other hand, further pollution can give rise to the induction of further environment-friendly technology and rejection of the traditional polluting technology, thus altering the course of technology use in the industry. The study also concluded that technological innovation in Malaysia improves the environmental quality by reducing the CO_2 emissions by implementing the new technology in the production process to produce more at the cost of fewer emissions. This outcome concludes that a more advanced technology can cause an increase in the economic growth, while on the other hand, a higher economic growth needs more advanced technology to keep the pace of the economic growth to the point, thus, confirming the feedback relationship.

5.2.2 Findings and Conclusions of the Second Objective:

The second objective of the study emphasized on the shifts in the economy from agriculture to industrial economy and then further to the services sector. The study focused on the impact of these structural changes (shifts) in the economy on the environmental quality in the country. The study focused on the industrial value added (INVAD) a proxy used to measure the structural changes in the economy. The third hypothesis of the study and the first under this objective is that structural changes in the economy will improve the environmental quality. The Johansen and ARDL bounds tests confirmed the existence of the long-run cointegration in the model. The study claimed that structural changes in the Malaysian economy have a negative relationship with the environmental pollution and concluded that structural changes in the economy can significantly improve the quality of the environment. The study also reported the short run results of the model and concluded that in the short-run structural changes has no insignificant impact on the quality of the environment.

The study further determined that economic growth, trade openness and increasing population bears positive and significant signs in the long-run. The study thus concluded that these determinants of carbon emissions can significantly increase the environmental pollution in Malaysia. The study also established a negative association between the GDP squared term and carbon emissions, thus concluding the presence of the EKC association between carbon emissions and higher GDP per capita. Furthermore, the study also hypothesized that trade openness in Malaysia will deteriorate the environmental quality. The results of the study showed that openness to trade bears a positive sign, thus, an increase in the international trade activities in Malaysia will lead to further environmental pollution. The causality results of the study detected a bidirectional causality between structural changes in the economy and carbon emissions, thus concluding that there is a feedback relationship between industry value added and CO_2 emissions in Malaysia and they can alter the course of each other. The causality results also revealed that trade openness has a unidirectional causal relationship towards the carbon emissions both in the long and short-run, thus validating the hypothesis that international trade will further deteriorate the environmental quality in Malaysia as openness to trade bears a positive sign.

5.2.3 Findings and Conclusions of the Third Objective:

The third objective of the research focused on the role of real interest rate in the environmental scenario in the income-pollution relationship. The study observed the impact of an increase or decrease in the rate of real interest and its implications in altering the income-pollution relationship. The long-run results of the model observed that the coefficient of the real rate of interest is positive and significant, meaning that the real interest rate cannot reduce the environmental pollution in the current situation as even the mean value of the real interest is higher than the inter-bank discount rate in the country. The short-run results of the study also concluded that an increase in the interest rate would increase the environmental pollution. The study further applied the Granger causality test and concluded that CO_2 emissions and international trade have a two-way causality association, while interest rate, per capita GDP, and energy use can cause the CO_2 emissions unidirectionally in the long-run. The study further concluded that variations in the interest rate in the economy have a bidirectional relationship with CO_2 emissions, and the study found a bidirectional causal relationship between the openness to trade and the rate of interest in the short-run in Malaysia. The study accepts the proposed hypothesis that variations in the interest rate can influence the patterns of CO_2 emissions, but these alterations in the income-pollution relationship did not validate the presence of EKC hypothesis.

5.3 Contributions and Implications of the study

The current study contributes to the literature, theory, methodology, and practice in the following way.

5.3.1 Contribution to Literature

Mainstream of the previous literature regarding the impact of energy use and economic growth on carbon emissions has focused on the use of total energy consumption while others have focused on the electricity consumption or other sources of energy individually (Begum et al., 2015; Cowan, Chang, Inglesi-Lotz, & Gupta, 2014; Hamdi, Sbia, & Shahbaz, 2014; Heidari et al., 2015; Kasman & Duman, 2015; Ozturk & Acaravci, 2013).

The important role of the structural changes in the economy (the transition of the economy from an agriculture economy to industrialized economy and further to a more services based economy) has been investigated very little in the previous literature, and the role of these structural changes in the environmental perspective is almost negligible and contradictory in the income-pollution literature (Dinda, 2004; Jayanthakumaran *et al.*, 2012; Kaika & Zervas, 2013; Smulders & Bretschger, 2000). The study measured the structural changes in the economy in the form of the share of the industry value added to the GDP. The current study focused on the role of structural changes in the economy in the income-pollution equation to investigate its impact on the quality of environment in the presence of economic growth, openness to trade, and energy consumption in the Malaysian context. The role of the transition of the economy from agriculture to industrialized and then to more services based economy and the findings of the impact of the structural changes in the income-pollution combination will be helpful to the existing literature as this determinant of carbon emission in the environmental perspective is new to the literature especially in the case of Malaysia.

The current study extended the previous work in the area by introducing the role of technological innovation in environmental perspective by considering the endogenous growth theory. Technological innovations are considered as one of the main determinants to improve the environmental quality along with financial development as targeted by the eleventh Malaysian plan. Technological innovation has been investigated by different researchers in different scenarios, including its role in improving the economic growth and energy efficiency and its relationship is inconclusive. Previous studies have focused on the research and development expenditures (R&D) as a proxy for technological innovation. The current study adopted the patent application as a proxy to measure the technological innovations as it is merely used in the environmental perspective. It is argued that patent data has some advantages while studying the environment-friendly role of the technological changes as it can provide with the advances in the technological fields which are narrowly defined and also can track the diffusion of technology on the basis of the application for patents by investors in different countries (Popp, 2005). This study is the first of its kind, especially in the case of Malaysia to focus on the role of technological innovation in the income-pollution equation. The findings of the research will be hopefully contributing a great deal to the existing literature.

The current study further adds to the literature by emphasizing the role of interest rate in the income-pollution equation to increase the understanding of the environmental Kuznets curve situation in the transitional economy like Malaysia. Previous studies have emphasized on the role of interest rate in the context of discount rate by considering the future costs of the climate change (Almansa *et al*., 2011; Almansa & Requena, 2007; Evans and Kula, 2011; Yang, 2003; Groom *et al*., 2005). Moreover, there is a clear contradiction on the rate of discounting the future costs of climate change. The present study extended the previous work by presenting the material related to the role of interest rate in affecting the income-pollution relationship via capital accumulation. The current study contributes to the extant literature related to the performance of interest rate in the environmental scenario because it has been ignored previously and it will open new insight into the field of EKC literature. The study reveals that environmental quality can be influenced by the fluctuations in the rate of interest, thus, is a necessary determinant of the carbon emission.

Finally, the current study also emphasized the importance of international trade and total population as previous literature evidenced these variables as significant determinants of the CO_2 emissions. Thus, the study will also add to the literature related to the role of international trade and population in the environmental perspective in the case of Malaysia.

5.3.2 Methodological Contribution

The current study contributes to the literature also from a methodological perspective as the role of the technological innovation, structural changes in the economy, and the impact of interest rate on the environmental quality has been ignored in the previous literature and can be the reasons for the gradual increase in the environmental pollution.

The current study utilized a comprehensive model in which all the variables including energy consumption, economic growth, CO_2 emissions, openness to trade, and technological innovation were emphasized combinenly at a time to inspect the occurrence of a long-run association. This combination of the determinants of the carbon emissions with the proxies used is the first of its kind at least in the case of Malaysia and is free of the omitted variable bias. Another methodological contribution of the study is the inclusion of technological innovation in the model as it provides an edge over the past studies because of the role of technological innovation, which is imperative for the improvement of the environmental quality, was previously ignore in most studies. Some previous studies emphasized the role of technological innovation in the form of research and development expenditures and spillovers from R&D (Apergis et al., 2013; Carolyn Fischer & Newell, 2008; Weber & Neuhoff, 2010). The current study used a different measure of technological innovation in the form of patent applications which is very novel and is superior to R&D expenditures in measuring innovation.

The current research methods applied in the study are not entirely new, but the way they are combined is the first of its type. Previous studies faced the problems of omitted variables bias, inappropriate data sets, and econometric techniques, etc. like using bivariate frameworks, especially in the case of Malaysia. This study covers these problems by selecting a multivariate framework and includes some control variables to eliminate the problem of omitted variables. The current research selected an appropriate econometric technique which can estimate the long and short-run estimates at a time. The study further used the bounds test and Johansen cointegration techniques to determine the presence of long-run cointegration. Moreover, the study applied the dynamic ordinary least squares (DOLS) method to validate the outcomes of the long-run estimates of the ARDL test. The DOLS approach to overcome the problem of endogeneity in the model which is rarely focused in the previous research. The study also focused on the tests of model misspecification to investigate the functional form of the models, the omitted variables bias by applying Ramsey's RESET test and the omitted variable likelihood ratio (LR) test. These tests of specification confirmed the validity of the estimates of the ARDL test. Last but not the least, the study applied the robust least square approach to making the estimates of the study more robust and viable.

5.3.3 Theoretical Implications

The present study overtly observed the long-run association between carbon dioxide emissions and its determinants in Malaysia. The study further focused on the causality relationships between the variables of the research. Furthermore, the research emphasized on the validation of the environmental Kuznets curve (EKC) hypothesis between CO_2 emissions and economic growth. In the course of action to investigate these objectives, the current research contributed to the existing literature. Moreover, the study delivers the evidence on the role of technological innovation, structural changes in the economy, and real interest rate fluctuation to reduce the environmental pollution by targeting the CO_2 emissions in the case of Malaysia. The current study highlights the anthropogenic global warming theory, the environmental Kuznets curve theory, endogenous growth theory, decoupling or dematerializing theory, and Ramsay-Koopmans theory in relation to the impact of different macroeconomic indicators of the environmental pollution by targeting the carbon dioxide emissions.

The Anthropogenic Global Warming theory posits that “man-made greenhouse gasses, mainly CO_2, methane, and nitrous oxides are responsible for the catastrophic warming trend globally since the Little Ice Age.” The study concluded that environmental pollution in Malaysia is increasing as the country is involved in economic and manufacturing activities to achieve the goal to become a developed nation by 2020. The economic growth of the country is considered as a backbone of the country and the economic activities in Malaysia are mostly based on the consumption of energy resources which are polluting the environment. Since the country is growing at a higher economic growth and is adding to the atmospheric CO_2 emissions in the process of production, thus, the economic growth in the country is at the cost of environmental quality. Moreover, the current study confirmed that higher level of economic growth (per capita income) can reduce the environmental pollution in Malaysia, thus, adding to the support of EKC hypothesis.

The strengths and progress of the economy of the country are dependent upon the energy resources. The main energy resources of the country are gas, coal, and oil, which are all polluting the environment. Thus, the utilization of these energy resources emits a huge amount of CO_2 into the atmosphere that provides support for the anthropogenic global warming theory. Trade openness is considered as a necessary component of a developing economy to meet the needs of its population in terms of goods and services and to keep the bilateral relations with other countries of the world. Trade openness can help improve the economic growth by attracting the foreign direct investments and can improve the exports and imports, thus leading to an increase in income per capita. The results of the study claimed that trade openness is deteriorating the environmental quality, so the exports based trade and the cleaner imports in the country will be helpful in improving the environmental quality. The results illustrated that trade openness in Malaysia is according to the race to the bottom hypothesis. This outcome may be because trade openness improves the economic growth of the country, and economic growth is polluting the environment, thus, the scale effect of trade may come into action to pollute the environment.

Moreover, the study focused the role of technological innovation in the environmental scenario to investigate whether the modern technology is environmentally friendly or not. The study revealed that technological innovation can improve the quality of the environment and this technological innovation is sponsored and supported by the financial development of the country. This finding of the study is relevant to the endogenous growth theory that financial development along with technological innovation can improve the economic growth without harming the environmental quality. According to the endogenous growth theory, economic growth can be significantly affected in the long run by the development of financial sector via technological innovations, investments in human capital (financial development) and knowledge.

The structural change hypothesis claims that the center of gravity of the economy can be shifted from agriculture, a low polluting, to a highly polluting industry (Panayotou, 2000). Similarly, with a gradual rise in the economic growth of the country, it can be brought back to services economy which is less polluting. The results of the study illustrated that structural changes in the Malaysian economy reduces the CO_2 emissions and improves the environmental quality. This is because the country first moved from the agricultural economy (low polluting) to an industrial economy (highly polluting) and then with the rise in the per capita income the country moved to the services sector economy (low polluting) as the share of the services sector to GDP is more than the share of the manufacturing sector. This environment-friendly role of structural changes is in line with the postulate of the structural change hypothesis.

Last but not the least, according to the Ramsay-Cass-Koopmans model the pollution will first increase with an increase in income, but after reaching a point the pollution will start decreasing and the income will still increase due to a decrease in the interest rate. The results of the study concluded that the real rate of interest in Malaysia cannot reduce the environmental pollution as the real rate of interest in the country in most of the years during the study period is greater than the inter-bank discount rate. Thus, a further increase in income will lead to more pollution and the study did not support the EKC hypothesis. This outcome of the study is in line with the Ramsey-Cass-Koopmans model. This outcome of the study is against the Rybczynksi theorem which postulates that a decrease in the interest rate (lower interest rate) can lead to more investment in the capital-intensive firms and there will be a shift of labour from labor intensive firms towards capital intensive industries, so more capital-intensive industries will be developed in comparison to labor-intensive industries.

5.3.4 Practical Implications

The current study encloses several implications for the policy makers, regulatory bodies, the public, and future researchers. The study is important to the policy makers and government regulatory bodies as the expected results of the study can provide some useful feedback on the relationship between the determinants of the carbon emissions in Malaysia, specifically, in the context of the EKC hypothesis. The study results have some practical implications in the field of technology, structural changes in the economy, interest rate, economic growth, and energy consumption to combat with the problem of environmental pollution and climate change. There are some real challenges to ensure the coherence of the policies related to environmental protection. There is also an urgent need to build a better coordination among various agencies and ministries. Similarly, on time and additional assistance on international basis for transfer of technology, financing, and capacity building may be helpful in shifting Malaysia towards low-carbon economic development.

The results of the study reveal some evidence on the role of technological innovation in the environmental perspective as the patent applications in the country has increased during the study period. Similarly, the importance of the changes in the structure of the economy can provide with an important policy implication regarding the environmental quality and the phase of economic activities. Moreover, the results of the study can be helpful in maintaining the changes in the rate of interest in the monetary policy regulations. Sidewise, the findings of the study are important to government regulatory bodies to impose some environmental regulations in the light of the outcomes of the study, especially in the perspective of economic growth, energy consumptions, and trade openness. The current study is vital to the domestic and international manufacturers in Malaysia, as the study provides them with a clear picture of the impact of different macroeconomic determinants of carbon dioxide emissions. This study can help them formulating a strategy how to improve the production without harming the environment.

Importantly, the results of the study concluded that technological innovation can improve the environmental quality which provides support for the endogenous growth theory that diffusion and innovation of technology can lead to better environment. This outcome is in fact in line with the New Economic Model (NEM) of Malaysia that has highlighted that the country should focus on the green growth and development in the pursuit to attain the higher-income nation’s status by 2020. The NEM sets out the “Polluter Pays” principle to preserve the environment and to justify removal of price controls and subsidies on energy to force the consumers and producers to pay a price almost equal to the social cost of energy consumption to make the country to be able to move towards green technologies and renewables. Thus, the study implicates that investing the tax money collected from polluters can encourage new technologies in the energy saving products and green energy areas. Furthermore, the findings of the study can be helpful to implement the Renewable Energy Act of 2011. This finding of the study very much supports the latest report of the IPCC's (IPPC, WGIII) in the perspective of diffusion and innovation of the technology as the instruments to improve the environmental quality by supporting the economic growth and determining the carbon intensity of energy and energy intensity of economic growth.

The finding of the study, that increase in number of patent applications (technological innovation) can improve the environmental quality, can be helpful to the manufacturers and government departments to focus on the deployment, replacement, and wide-scale upgrading of the current technologies with the best available technologies in the industries, which are not energy-centered, to lessen the intensity of energy use. Technological innovation in terms of upward shift in the patent application can be helpful in the implementations of government policies such as National Policy on Climate Change, National Renewable Energy Policy and Action Plan, National Green Technology Policy among others as technology is the basic fuel for the implementation of these environment related policies. This outcome of the study has also implications for the firms and industries as if energy efficient technologies are adopted by the firms, they may experience a decrease in their production cost aside from satisfying the level of emissions, money saving, corporate reputation, and a better chance for society to fight the environmental pollution. These benefits provided by the innovation can be partially internalized and if these benefits are not because of the costly R&D expenditures, like in this case, there is a chance that the firm may experience more incremental innovation for free through learning by doing. For example, there is an equal chance that over time firms may develop a better technique of production by incorporating the cleaner fuels and modern technology in the process of production. The results of the study implicate that the development of competitive technology, higher value-added industries, and the improvement in the human capital via improved access to high quality education, vocational trainings, and other necessary skills can lead to an improvement in environmental quality. A feasible way to enhance this shift in the technology are joint public-private initiatives and investments in renewables and technologies that are energy efficient. This outcome of the study can be helpful to the Ministry of Science, Technology and Innovation (MOSTI) in improving the competitiveness in the fields of technology, science, and innovation via sustainable development and knowledge generation.

The study also revealed that structural changes in the economy are environment-friendly, thus, the government should formulate such policies that can further enhance the environmental quality by emphasizing more on the services sectors rather than manufacturing sectors because a movement towards services sector economy can improve the environmental quality in the country. This result is because of the composition effect of economic growth as at first the economy moved from agriculture to industrialization on the path of economic growth, thus, increasing the environmental pollution. Moreover, when the balance of economic growth shift towards more services based production the domestic environmental pollution reduced due to changes in the demand and supply side changes. The outcome of the study has implication in the field of economic growth as shift in the composition of the economy delink or decouple the material use form economic growth by moving from more manufacturing activities towards more information based services sector to carry out the production, thus leading to a decrease in the use of energy and ultimately environmental pollution. The results of the study reveal that a shift towards services sector can improve the environmental quality but the impact can be more enhanced if the structural change is accompanied by proper improvements in technology, as technology and structural change can effectively reduce the environmental pollution. The results reveal that only the shift towards service sector is not sufficient for the inverted U-shaped relationship between economic growth and CO_2 emissions because in the later part the pollution may start rising again, but if it is accompanied by advanced technology the decreasing impact of economic growth can be sustained in the long-run.

The results further revealed that fluctuations in the real interest rate can affect the income-pollution relationship and the current state of interest rate in Malaysia can increase the environmental pollution with an increase in the income as people will be more oriented towards saving to enjoy the high rate of interest rather than investing in environment-friendly capital and projects. The current outcome of the study, that higher interest rate than discount rate add to the environmental pollution is negating the Rybczynksi theorem of the impact of interest rate on the environment. The Rybczynksi theorem postulates that a decrease in the interest rate (lower interest rate) can lead to more investment in the capital-intensive firms and there will be a shift of labour from labor intensive firms towards capital intensive industries, so more capital-intensive industries will be developed in comparison to labor-intensive industries. While on the other hand, high interest rate will not allow the investors to invest in capital-intensive industries, thus there will be more labor-intensive industries and less pollution.

The current outcome of the study, that high interest rate pollutes the environment is supporting the Ramsay-Cass-Koopmans model which postulates that fluctuations in interest rate can affect the income-pollution relationship. If the interest rate is higher than the discount rate it can add to environmental pollution by positively affecting the CO_2 emissions, while on the other hand when the per capita income increases it can lead to decrease in the interest rate. When the interest rate in the country is lower than the discount rate, it can lead to more investment the saving amount in the environmental friendly, energy efficient, green, and welfare projects which will lead to a betterment in the environmental quality. Thus, the current study implicate that Ramsey-Cass-Koopmans model is more beneficial for environment. This outcome of the study has the implication towards monetary policy of the country as the real interest rate is controlled by monetary policy in an economy. The current study has is helpful to the monetary policy to reduce the interest rate from 4.42% in 2013 and 4.99% in 2015, down to 2.60% because the discount rate in the country is 2.61%. This outcome is in line with the current decrease in the interest rate in 2016 down to 3%. The current study implicates that high interest rate will lower the stock market outcome, business profits, consumer spending, home sales, and borrowings, while on the other hand, a low interest rate can improve the stock market outcome, business profits, consumer spending, home sales, and borrowings.

Another implication of the low interest rates is that it can be helpful in stimulating and steering the investments in environmental protection and green technology. Low interest rates can represent both the fiscal incentives and government policies of investment. Low interest rates can be helpful in indirectly steering the investments as discount in the rate of interest represent the intention of the government economic policy which can attract private investors to the areas of interest to national policy without harming the market resource allocation. Interest rate discounts can also be helpful in minimizing the danger of financial losses which may be the case when the government subsidies environment friendly projects. Even if the projects fail the loss to the public finance will be lower compared to other direct subsidies offered by government and will reduce the risk of fiscal subsidies. Similarly, in the presence of low interest rates, investments by the firms and companies will be more profitable and there will be a decrease in the cost of financing the green investments. Discounts in the interest rates can provide financial support to industries involved in green projects and it can attract more private investments by developing subsidized projects and industries. Low interest rates can achieve more social benefits rather than direct subsidies as the cost of interest rate discounts is low compared to direct subsidies.

In the case of Malaysia financial development can be a good tool to decrease the environmental pollution in the long-run as it has negative and significant impact on the CO_2 emissions both in the short and long-run. Thus, if there is a continuous loan provisions to the firms and projects which are green, environment-friendly, energy efficient, renewable, and energy saving, financial development may prove a very useful tool to handle the problem of environmental pollution in the short and long-run. The results of the study can be helpful to Bank Megara Malaysia (BNM), Security Commission Malaysia (SC) and Labuan Financial Services Authority (Labuan FSA) in issuing loans. Financial development can affect the environmental quality via three channels, including expanding domestic output (scale effect), increasing the investment activities and opportunities (business effect), and developing the efficiency of the stock market (wealth effect). A developed financial sector in the country can contribute a lot to encourage and expand the domestic production by providing loans to the domestic manufacturers to compete with the global counterparts to meet the demand of exports. Secondly, a developed financial sector can be helpful in increasing the opportunities for business as the financial institution can provide loans and invest in some environment-friendly projects like public green parks, energy efficient industries, new technology, green businesses, and renewables. Last, but not the least, the wealth effect of financial development can be helpful in improving the value of the green and energy efficient stock market products. Developed financial sectors can also be useful in attracting the FDI, and consequently, advanced activities in the field of research and development can improve the environmental quality. Furthermore, developed financial sector in Malaysia can encourage the public listed companies to utilize advanced technology which is energy efficient, and subsequently can reduce the carbon emissions.

Furthermore, FDI inflows can transfer new technologies, new ideas, and managerial skills to Malaysia. The domestic firms may experience an increase in their performance and productivity due to improvements in technology. The net inflow of FDI in the country can be used as a stimulus and an engine for the sustained economic growth in Malaysia. The results implicate that net inflows of FDI from the MNCs can spread the new technologies to the domestic counterparts in the host country. Since the FDI in Malaysia is attracted mostly Japan and China who have modern technology and Malaysia is relatively a bit low on the advanced technology. Thus, as the lag of technology is not that big, Malaysia can raise the emission standards by liberalizing FDI which may lead to a "race to the top" effect, thus improving environmental quality in the country. The 'race to the top' hypothesis in the case of FDI inflows in Malaysia is because of the enhanced level of human capital in the areas of education and healthcare in the country which is one of the most important factor among others that can attract the foreign investors to invest in the country as the country has high-quality and productive workforce which is helpful to both the foreign and domestic investors.

It is claimed that the association between environment and economic growth is very complex and there are different other constructs which can affect the relationship between the both. The relationship between economic growth and the environment is dependent upon the composition and scale of the economy- as the share of the services sector and manufacturing industries to GDP- and technological changes as they can increase the production while consuming the same amount and releasing less pollution in the atmosphere and driving the economic growth. The study results concluded that economic growth is at the cost of environmental pollution, which is in line with the IPCC's fifth assessment report[15]. The findings of the study can be helpful to the government and policy makers in implementing the 11th Malaysia plan to change the slogan of the 'grow first, clean up later' development model towards a low carbon, resilient, socially inclusive, and resource efficient development model to ensure the

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future gains. The outcome of the study can be helpful in altering the top-down mechanism of economic growth towards the bottom-up approach as per the 11th Malaysia Plan, where local authorities can work side by side with the government and stakeholders.

The results concluded that openness to international trade is deteriorating the environmental quality in Malaysia as the country is trying to catch up the demand by increasing economic activities, thus, energy consumption. Trade openness is said to have direct and indirect effects on the environmental quality. In the case of Malaysia, the results implicate the currently in Malaysia the scale effect of trade openness is helpful to increase the economic growth quite positively as there is an increase of trade volume (trade %) from 79% in 1971 to 142% of GDP in 2013. The results of the study have also shown a negative impact of higher income on the environmental pollution, meaning that with high per capita income the government and people may invest in the welfare projects and environmental protection measure which can lead to a decrease in the environmental pollution. This mitigation can be further enhanced with an increase in the demand for the environmental quality and then if environmental regulations become stricter, thus leading to technique effect. In the current situation scale effect is dominant over the technique effect as the volume of trade has increase many folds relatively to the advancements in the field of technology. Thus, we can see an increase economic growth due to scale effect of trade openness but no such improvement in the environmental quality due to technique effect. Trade openness in Malaysia is according to the “race to bottom hypothesis” which leads to an increase in the pollution.

Since Malaysia is a major exporter of the polluting products, including liquefied natural gas, electrical and electronic products, petroleum chemicals, palm oil, and others, thus, the composition effect of the trade come into action and the composition of the trade in Malaysia is more inclined towards manufacturing products rather than towards more services sectors. The results reveal that due to trade openness there occur a shift in the factors of production form low-comparative advantage sectors such as forestry, farming, petroleum, and natural gas to relatively more comparative advantage sectors such as industries which are more energy intensive and polluting such as manufacturing, chemical, air transport, electricity, and textiles. Since most of the trading partners of Malaysia (developing country) are developed economies such as Japan, Singapore, UK, China, and USA among others, and they have strict environmental regulations, thus, the comparative advantage of the of pollution-intensive goods will shift towards Malaysia due to relatively loose environmental regulations. This outcome of the study can be helpful to Ministry of International Trade and Industry (MITI) in altering the patterns of trade to make Malaysia a preferred destination for international investments and one of the most competitive trading nations by 2020. This outcome of the study can also be helpful in planning, legislating, and implementing the international trade and industrial policies to target the production of high value-added goods and services.

This outcome that trade openness deteriorates the environmental quality is per the Heckscher-Ohlin trade theory, which postulates that, country will produce and export those goods in which it has comparative advantage and will import those goods which are comparatively cheaper in other countries. Thus, the study implicates the international trade in the country is not environment-friendly as the country has a comparative advantage in some of the energy-intensive and polluting manufacture products. Thus, the manufacturing of these polluting products to meet the demand for exports, and the dirty imports of energy-intensive goods and services to meet the domestic demand for these products lead the composition effect of trade to take over the technique effect. Thus, the openness of trade in the country can lead to an increase in the environmental pollution. The results implicate that trade openness is causing harm to the environmental quality because the textile, automotive, manufacturing, and chemical industries are expanding due to comparative advantage of the country in the area and international demand. This balance can be adjusted by focusing on policies that can increase exports of the country by accelerating the value chain of cleaner products, increasing support from external experts of the industry, and maximizing the trade opportunities with green partners that in turn will improve the balance of trade in environmental perspective.

The results concluded that environmental quality is deteriorated by the vast utilization of the non-renewable energy resources. The results of the study have implication to the "Energy Commission (Suruhanjaya Tenaga), in the field of subsidizing the energy and fuel as both the subsidization of fuel and energy are problematic because subsidies accounts for the 10% of total tax revenue in 2010 in Malaysia. Thus, these subsidies can be a burden on the government budget and can boost the use of these mostly non-renewable energy resources. Due to these high fuel and energy subsidies the per capita consumption of fuel in Malaysia is 4.5 times that of Thailand. This outcome is in fact in line with the New Economic Model (NEM) of Malaysia, and can be helpful in implementing the NEM as to sets out the "Polluter Pays" principle to preserve the environment and to justify removal of price controls and subsidies on energy to force the consumers and producers to pay a price almost equal to the social cost of energy consumption to make the country to be able to move towards green technologies and renewables. The results of the study are in support of the government initiatives to eliminate the subsidies on cooking gas, gasoline, road tolls, and electricity use. Removal of these subsidies can flourish a healthy competition from renewable energy resources in the power sector as oil and diesel are relatively more expensive without subsidies. Moreover, the elimination of subsidies from these non-renewable energy resources can raise the consumer demand for alternative renewable energy resources. The low prices of LNG and fuels due to subsidies are also responsible for the smuggling of huge amount of LNG to other countries like Vietnam, Thailand, and Laos. Last but not the least, the removal of subsidies can also flourish other healthy and environment-friendly schemes such as welfare and research and development activities as this number of subsidies can be spent in the improvement of environmental quality.

Furthermore, in the case of Malaysia most of the energy related pollution is because of the production of electricity as electricity generation is responsible for the 54% of total CO_2 emissions in the country. The results of the study are in line with the Feed-in-Tariff (i.e. a 1% extra charges in the bill on those who consumes more than 300 units of electricity per month) and it can work as an incentive for saving energy and is a motivation to prevent the use of extra electricity and to adopt the energy efficiency measures and renewable energy. Since the dependence of the electricity generation on the coal-based power plants is increasing due to the decrease in the production and limited resources of natural gas in Malaysia. Thus, the findings of the study can be helpful to the "Energy Commission, General Oceanic In; MATRIX ENERGY (M)

SDN. BHD; Markland Specialty Engineering Ltd; and other small electricity producing agencies in altering the traditional modes of electricity generation which are more inclined towards coal, and gas to more renewable basis such as building dames to generate electricity from water resources. Utilizing the biofuels, biomass, and bio wastes of the palm oil plantations. The installations of solar power plants can also be helpful to the electricity generating entities, as very much on the equator line, Malaysia receives at least 6 hours of peak sun rays on average during the day time. The wind power plants in some parts of the country, where the speed of wind is favorable to produce the electricity, can be helpful to reduce the polluting effect of electricity to some extent. Since the government of Malaysia has promised to reduce the CO_2 emissions by 40% by 2020, thus, one of the basis way to accomplish this goal is to reduce the CO_2 emissions from the electricity generation and this can be done by altering from gas and coal towards more hydro and renewable such as biomass and biofuel. The study implicated that if the country continued the generation of electricity with the current percentage of fuel mix the projected contribution of coal, gas, hydro and oil in 2030 will be 49%, 44%, 5.7%, and 1% respectively which is not desirable as it is coal and gas dominant, thus, the study suggest the change in the percentage contribution in the fuel mix. This finding of the study is in line with the vision 2020 as the country should change the dependence on gas (52.7%), coal (38.9%), oil (1%) and hydro (7.3%) in 2012 to 40% on gas, 23% on coal, and 30% hydro to reduce the CO_2 emissions to the desired level by 2020.

The results inferred that an increase in the population of the country will further aggravate the environmental population. The increase in population will enhance the concentration of carbon dioxide in the atmosphere as the per capita carbon emissions is dependent on the number of metric tons emitted per person. The results disclosed that increasing population can deteriorate the environmental quality depending on the local conditions, including the deficiency in the regulatory policies. In lager cities like Kuala Lumpur with highest population density in the country if there will be loose environmental regulations, increasing population will worsen the environmental quality. Thus, the study suggest that government should focus more on the environmental regulation in performing the economic activities, including industrial production, waste disposal, and the installation of new environment-friendly technologies to ensure efficient use of the energy resources with higher production and low pollution.

The findings of the current study have implications for the public to make them aware about the relationship of human activities and society with ecology, and their consequences on the quality of environment. Thus, the study implicates that there is a need of deep changes in educating the school and college students in the field of technology, science, and sustainability. The importance of technology, modifications in technologies in numerous cultures, and the possible consequences of implementing the technology which the society may experience should be focused to make the students better understand the process of technological change. Moreover, a better understanding about the sustainability in a holistic way by guiding and teaching them regarding the connection of values and institutions with technology, society and economy with ecology, consumers with governments and producers, and the connection of equity with welfare can be of great value in future. The results implicate the encouragement of the environmental projects related to sustainability and the involvement of the academic institutions in the environment related activities and projects to create awareness about the causes of environmental pollution, their possible solutions, and to guide the public to protect the environment from further degradation.

5.4 Policy recommendations

The results of the study reveal that energy consumption is Malaysia is polluting the environment as most of the energy resources in the country are non-renewable and emit a huge amount of GHG, especially carbon dioxide. Thus, the policy makers should focus on other alternate policies, including the conservation of energy, encouraging the efficient use of energy, decreasing the intensity of the non-renewable energy, and focusing more on the utilization of cleaner and greener sources of energy including biomass, hydro, wind, and solar energy. The results suggest that the government of Malaysia should revise the pricing mechanism of energy to stimulate and reassure energy efficiency in the industrial, commercial, and residential sectors. The current mechanism involves high subsidies on the energy use, which are obstructing the improvement efforts in the field of energy efficiency. Thus, the government should encourage investments in making the energy use efficient by providing some incentives while focusing on a gradual reduction in the energy subsidies which can be used as incentives for energy efficient investments. The government should also promote the energy efficiency by public awareness campaign, labelling energy, training and workshops, and publication regarding the advantages of energy efficiency. The government should also emphasize on the implementation of the capture and storage of CO_2 (CCS) technologies on a large scale in the country to reduce the fossil fuel based power plant's GHG emissions lifecycle. Last but not the least, the government and policymakers should also focus on the enactment of some regulations in the law regarding the energy efficiency.

The results conclude that upward shift in the number of patent application in the country can improve the environmental quality. Thus, the policy makers should focus on the transformation to renewable energy, low carbon technologies, and energy efficiency to maintain the growth of the economy in the long-run by targeting CO_2 emissions. Furthermore, the government of Malaysia should provide some incentives to the foreign investors and companies to encourage them to combat the environment pollution by acquiring their technical expertise, related technologies, and innovative environmental practices. The government of Malaysia should provide the foreign companies with some incentives for forest plantation projects, treatment for disposal of hazardous and toxic wastes, recycling of wastes, renewable energy sources to generate energy, energy conservation, and the accelerated capital allowance for the better management of the environment and to encourage their environment-friendly activities in the country.

The policy makers should also emphasize on enhancing the financial flexibility by executing more practical spending procedures and augmenting the revenue to make sure that the fiscal position of the country is sustainable in the long term. The government and policymakers also should encourage the firms to embrace new technologies with fewer emissions during the process of production by subsidizing the firms with less emission. Moreover, the country should focus more on the loans and subsidies to the firms that are involved in the environment-friendly projects, and the capital should be invested more in the green facilities such as waste disposal and installation of new environment-friendly technologies. The financial institutions such as banks may also offer interest discounting and should include some conditions regarding carbon emissions while offering financial products including real estate investment term loans and business vehicles to boost up the investments in environment-friendly and energy efficient technology. The government should also reduce the investments in electricity generation from the traditional technologies based on fossil fuels and alter these investments towards the low-carbon electricity production (e.g. nuclear, CCS based electricity generations, and renewables).

The policy makers should focus on the financial incentives (monetary benefits), fiscal incentives (tax measures) and other such incentives to investors, entrepreneurs, organizations, and MNCs, that can attract the inflows of FDI in the country to improve the environmental quality and continue long-run sustainable economic growth. The government should attract more FDI as the MNCs can spread the new technologies to the domestic counterparts in the host country. The government should guide the multinational companies (MNCs) in a proper direction to use the FDI to develop the technology and capital-intensive industries, and to optimize the industrial structure to minimize the pollutant emissions. The regulatory bodies should also focus on the improvement of environmental management and supervision of the FDI to reduce the transfer of pollution in the shape of FDI. The country ought to focus on the avoidance of environmental degradation and the promotion of environmental protection via the corresponding expertise and transfer of technology with the MNCs.

Based on the findings of the study that structural change (shift from more manufacturing to services sector activities) can improve the environmental quality, the study suggests that the government should focus more on the information-based services to promote economic growth as it is more services based rather than production based, thus, is less polluting. The study suggests that the policy makers should emphasize on distribution, transportation, and sale of the goods from producer to consumers by providing the services of retailing and wholesaling facilities rather than manufacturing these goods which emit pollutants in the atmosphere. The government should also encourage the multinational companies (MNCs) to invest in knowledge and information based industrial sector activities and to share the corresponding know-how and technology transfer.

The results concluded that the current interest rate in Malaysia is high and this high interest rate can lead to pollute the environment, thus, the findings suggest that the monetary policy regulators should also emphasize on the fluctuations in the rate of interest rate to keep the real interest rate lower and thus encouraging the public and investors to invest in environmental projects and capital formation rather than saving. The amount which currently is saved can be utilized in the environment-friendly projects and welfare of the society. The results under the Ramsey-Cass-Koopmans model suggests that the rate of interest should be lower than the prevailing discount rate in the economy where a further increase in income will decrease the environmental pollution in an environment-friendly way while keeping the growth of the economy high. The results implicate that in the environmental scenario monetary policy authority should lower the real rate of interest to encourage and attract investments in the environment-friendly projects such as national park projects, and the low-cost credits can also be used to purchase inputs that can promote the intensification and investments in the soil conservations. The interest rate in 2013 was 4.42, it increases to 4.99 in 2015, while the discount rate is lower, which is 2.61, so the government should reduce the interest rate down to 2.60 at least to cope with the environmental pollution. Similarly, the direct consequences of higher labor intensity (lower capital intensity) may lead to an improvement in the environmental quality. The monetary policy authority should lower the interest rate in country as low interest rate is beneficial to outcome of stock market, business profits, consumer spending, home sales, and borrowings.

The results conclude that trade openness in Malaysia is at the cost of environmental quality thus, the government should impose some tight trade limitation on the imports of the high energy-intensive products and on the investments in the energy-intensive products. The imports of the country (US$207.5 billion) are greater than the exports of the country (US$175.7 billion) and the main trade partners are the developed economies. Under the ASEAN Free Trade Agreement, Malaysia has low levels of imports tariffs so the imports of these high energy and carbon intensive products can increase the CO_2 emissions alongside economic growth. Thus, the results of the study also suggest that the government and policy makers in Malaysia should force the domestic manufacturers to prepare the export products per the international environmental standards as most of the exports of Malaysia are going to European Union countries and they have strict environmental regulations. Thus, if the export products of Malaysia are not up to the merit on environmental standards the exports of the country will drop and thus, will affect the economic growth of the country. Therefore, it is obvious for Malaysia as a fast-growing country of the world to make sure that the business activities, especially investments, finance, and trade activities are directed towards sustainable economic, social, and environmental development goals via the incentives, voluntary agreements and regulations.

The composition and direction of the trade has not been changed that much during the past decades as reported by the 10^{th} Malaysia Plan (2011-2015). The composition of the trade consists of low end value of exports, the manufacturing sector dichotomy, and the dependence of the export sector on the low-level technology without any innovation in the field of technology that can create a competitive edge. The findings of the study recommend that government should focus on the reduction of imports of the required fuels. The policy makers should also focus on some environmental reforms in the resource-extracting or pollution-intensive sectors, and should emphasize on some welfare improving trade reforms to protect further intense environmental degradation due to openness of trade. The impact of trade openness on the environment depends upon some factors in the country, thus, the government should focus to improve the level of development, comparative advantages to be more services oriented, trade of less energy-intensive products, improvement of environmental awareness, and implementation of environmental policies. `Similarly, the impact of environmental quality in Malaysia can be improved via removing the tariffs in the polluting industries that are highly protected or removing the export subsidies in those sectors, but, this may lead to losses in the competition. The study thus suggests that the policy makers in the country should lead the flow of investments on the path of sustainable development and trade-induced technical change by adopting suitable policy tools.

The findings of the study concluded that different resources of energy are polluting the environment, thus, the government bodies should better manage electricity demand, reduce the energy consumption per GDP ratio to 1:1 which is currently higher thus leading to pollution. The energy and fuel subsidizing authorities should decrease or completely remove the subsidies from fuels and should move to the market pricing which can save some money that can be spent in energy efficient projects. The government should ensure fast and strong economic growth via the sustainable and efficient use of resources, socially inclusive, less carbon intensive and more climate change resilient policies. The government should focus on the renewable energy projects like solar photovoltaic, biomass, and hydro to change the current energy mix to reduce the dependency on the non-renewable energy resources. The regulatory bodies should encourage the energy efficiency in the industrial sector, supply and demand side efficiency in commercial and domestic sectors to ensure the pollution reduction.

5.5 Limitations and Future Research

Alongside the strengths of the present study, there are some limitations of the current study. Firstly, the study analyzed the annual data on the determinants of the CO_2 emissions over a period 1971-2013 because it is the longest period available. The future studies can extend the period of the study, including the data from most current years, especially if the data on carbon emissions per capita is available. The data on carbon emissions was only available up to 2013 from all the sources, including WDI, index Mundi, CDIAC, GFDD, BP, and DOSM.

The study further collected the data on technological innovation (patent applications) over a period 1985-2013 because there are no data available on patent applications prior to 1985. The study focused on the patent applications in the current study because the patent applications have superior properties over research and development expenditures. Future researchers can target innovation count, labor productivity or intellectual property rights index as the proxy for technological innovation.

Another limitation of the study is the smaller period 1987-2013 on the real interest rate as there is no prior data available on the interest rate in the case of Malaysia. The study results are also limited in terms of implications as the results are based on a short period of time and may change over a long period.

The current study covers the objectives of the study well but it did not include some other important determinants including urbanization, transportation, and deforestation, as they were utilized previously. The future researchers can emphasize the role of urbanization, institutional quality, carbon tax if implemented (as discussed in New Economic Model) and other potential determinants of carbon emissions to encompass some new insights into the area.

Finally, the macroeconomic determinants of carbon dioxide emissions in Malaysia provides a clear understanding of the current research, but the generalization of these results to other countries should be made carefully due to the differences in the economic and social conditions, environmental regulations, the energy mix, and other factors.

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APPENDIX A

ROBUST LEAST SQUARE ANALYSIS

Robust Least Square Results for First Objective

Dependent Variable: LNCO2
Method: Robust Least Squares
Date: 08/08/16 Time: 16:10
Sample (adjusted): 1987 2013
Included observations: 27 after adjustments
Method: M-estimation
M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)
Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
LNCO2(-1)	0.207214	0.095244	2.175615	0.0296
LNCO2(-2)	-0.348773	0.073847	-4.722892	0.0000
LNEC	0.563575	0.119213	4.727458	0.0000
LNEC(-1)	-0.645638	0.153712	-4.200316	0.0000
LNEC(-2)	1.007065	0.153135	6.576301	0.0000
LNGDPPC	-26.14951	9.064892	-2.884702	0.0039
LNGDPPC(-1)	63.00397	10.47194	6.016455	0.0000
LNGDPPC(-2)	-1.200085	0.192506	-6.234007	0.0000
LNGDP2	1.486174	0.509937	2.914425	0.0036
LNGDP2(-1)	-3.494288	0.588969	-5.932886	0.0000
LNTI	-0.470504	0.097301	-4.835557	0.0000
LNTI(-1)	0.040521	0.106220	0.381481	0.7028
LNTI(-2)	-0.460963	0.086298	-5.341504	0.0000
LNTRADE	0.045803	0.017173	2.667229	0.0076
LNTRADE(-1)	-0.032009	0.011417	-2.803674	0.0051
LNTRADE(-2)	-0.030256	0.013098	-2.310089	0.0209
C	-158.4762	14.04750	-11.28145	0.0000

Robust Statistics

R-squared	0.795420	Adjusted R-squared	0.468091
Rw-squared	0.999573	Adjust Rw-squared	0.999573
Akaike info criterion	55.14219	Schwarz criterion	91.74583
Deviance	0.003698	Scale	0.010175
Rn-squared statistic	13377.01	Prob(Rn-squared stat.)	0.000000

Non-robust Statistics

Mean dependent var	1.676890	S.D. dependent var	0.364864
S.E. of regression	0.050870	Sum squared resid	0.025877

Robust Least Square Results for Second Objective

Dependent Variable: LNCO2
Method: Robust Least Squares
Date: 08/18/16 Time: 13:09
Sample (adjusted): 1973 2013
Included observations: 41 after adjustments
Method: M-estimation
M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)
Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
LNCO2(-1)	0.334353	0.136602	2.447645	0.0144
LNEC	0.500353	0.203383	2.460154	0.0139
LNGDPPC	8.599020	5.825533	1.476092	0.1399
LNGDPPC(-1)	-25.46954	6.694215	-3.804709	0.0001
LNGDPPC(-2)	21.04346	5.238349	4.017193	0.0001
LNGDP2	-0.489015	0.343764	-1.422531	0.1549
LNGDP2(-1)	1.504373	0.392980	3.828113	0.0001
LNGDP2(-2)	-1.258711	0.306738	-4.103536	0.0000
LNINDVA	0.186925	0.310930	0.601181	0.5477
LNINDVA(-1)	-1.447127	0.382294	-3.785375	0.0002
LNTRADE	-0.154674	0.183011	-0.845160	0.3980
LNTRADE(-1)	0.583412	0.196555	2.968187	0.0030
LNPOP	-17.94162	7.713692	-2.325944	0.0200
LNPOP(-1)	17.86863	7.757579	2.303377	0.0213
C	-16.40532	12.90259	-1.271475	0.2036

Robust Statistics

R-squared	0.817632	Adjusted R-squared	0.719434
Rw-squared	0.997563	Adjust Rw-squared	0.997563
Akaike info criterion	73.34766	Schwarz criterion	108.1461
Deviance	0.050415	Scale	0.031006
Rn-squared statistic	5648.685	Prob(Rn-squared stat.)	0.000000

Non-robust Statistics

Mean dependent var	1.335932	S.D. dependent var	0.570713
S.E. of regression	0.057122	Sum squared resid	0.084836

Robust Least Square Results for Objective Five

Dependent Variable: LNCO2
Method: Robust Least Squares
Date: 08/18/16 Time: 13:17
Sample (adjusted): 1989 2013
Included observations: 25 after adjustments
Method: M-estimation
M settings: weight=Huber, tuning=1.345, scale=MAD (median centered)
Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
LNCO2(-1)	0.345078	0.173993	1.983281	0.0473
LNEC	0.750270	0.248065	3.024487	0.0025
LNEC(-1)	-0.684256	0.285832	-2.393909	0.0167
LNEC(-2)	1.031734	0.334720	3.082375	0.0021
LNGDPPC	-110.8152	43.75824	-2.532443	0.0113
LNGDPPC(-1)	109.5865	40.86458	2.681698	0.0073
LNGDPPC(-2)	-1.854514	0.430465	-4.308165	0.0000
LNGDP2	6.280893	2.464527	2.548519	0.0108
LNGDP2(-1)	-6.149177	2.312857	-2.658692	0.0078
RIR	0.013338	0.004167	3.201046	0.0014
RIR(-1)	0.005430	0.002402	2.260310	0.0238
LNTRADE	0.130237	0.046154	2.821782	0.0048
LNTRADE(-1)	-0.122628	0.044238	-2.772039	0.0056
LNTRADE(-2)	-0.103021	0.045218	-2.278329	0.0227
C	10.43503	22.76140	0.458453	0.6466

Robust Statistics

R-squared	0.934426	Adjusted R-squared	0.842623
Rw-squared	0.996517	Adjust Rw-squared	0.996517
Akaike info criterion	118.9083	Schwarz criterion	132.4781
Deviance	0.011443	Scale	0.011658
Rn-squared statistic	2205.638	Prob(Rn-squared stat.)	0.000000

Non-robust Statistics

Mean dependent var	1.738966	S.D. dependent var	0.300041
S.E. of regression	0.055314	Sum squared resid	0.030596

APPENDIX B

QUARTERLY DATA ANALAYSIS

Quarterly Data Analysis for Objective One

ARDL Cointegrating And Long Run Form
Dependent Variable: LNCO2
Selected Model: ARDL(3, 3, 2, 1, 0, 1)
Date: 12/24/16 Time: 14:52
Sample: 1985Q1 2013Q4
Included observations: 113

Cointegrating Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNCO2(-1))	0.488453	0.086878	5.622258	0.0000
D(LNCO2(-2))	0.232315	0.093241	2.491560	0.0144
D(LNEC)	1.040620	0.141724	7.342589	0.0000
D (LNEC (-1))	-0.378744	0.268664	-1.409734	0.1618
D (LNEC (-2))	-0.254612	0.141102	-1.804452	0.0743
D(LNGDPPC)	-7.357637	7.345973	-1.001588	0.3190
D (LNGDPPC (-1))	0.330846	0.218557	1.513770	0.1333
D(LNGDP2)	0.399881	0.415548	0.962299	0.3383
D(LNTI)	-0.095671	0.029042	-3.294235	0.0014
D(LNTRADE)	0.010390	0.007637	1.360442	0.1768
CointEq (-1)	-0.198366	0.037453	-5.296392	0.0000

Cointeq = LNCO2 - (0.1741*LNEC + 25.3762*LNGDPPC -1.3852*LNGDP2 -0.4823*LNTI -0.0296*LNTRADE -28.2104)

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNEC	0.174095	0.195108	0.892298	0.3744
LNGDPPC	25.376204	4.308413	5.889919	0.0000
LNGDP2	-1.385221	0.246452	-5.620650	0.0000
LNTI	-0.482293	0.125996	-3.827832	0.0002
LNTRADE	-0.029643	0.025853	-1.146594	0.2544
C	-28.210425	4.598175	-6.135135	0.0000

Quarterly Analysis for Third Objective

ARDL Cointegrating And Long Run Form
Dependent Variable: LNCO2
Selected Model: ARDL(1, 1, 1, 1, 0, 1)
Date: 08/10/16 Time: 10:53
Sample: 1987Q1 2013Q4
Included observations: 107

Cointegrating Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNEC)	0.506322	0.263938	1.918336	0.0580
D(LNGDPPC)	9.409016	3.836081	2.452768	0.0160
D(LNGDP2)	-0.496963	0.218756	-2.271772	0.0253
D(RIR)	-0.000575	0.000867	-0.662433	0.5093
D(LNTRADE)	0.045071	0.021524	2.093964	0.0389
CointEq(-1)	-0.155879	0.050632	-3.078649	0.0027

Cointeq = LNCO2 - (0.1180*LNEC + 11.3325*LNGDPPC -0.5616
*LNGDP2 -0.0037*RIR -0.0988*LNTRADE -52.7907)

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNEC	0.117976	0.512935	0.230001	0.8186
LNGDPPC	11.332475	5.207573	2.176153	0.0320
LNGDP2	-0.561550	0.272514	-2.060628	0.0420
RIR	-0.003686	0.005925	-0.622091	0.5354
LNTRADE	-0.098776	0.069320	-1.424919	0.1574
C	-52.790661	21.451799	-2.460897	0.0156