Faculty of Economics and Business

Dynamic Interaction between Economic Growth and Energy in Malaysia

Tan Chiang Ching

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DYNAMIC INTERACTION BETWEEN ECONOMIC GROWTH AND ENERGY IN MALAYSIA

TAN CHIANG CHING

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ABSTRAK

INTERAKSI DINAMIK ANTARA PERTUMBUHAN EKONOMI DAN TENAGA DI MALAYSIA

Oleh

TAN CHIANG CHING

Tesis ini menyelidik hubungan antara pertumbuhan ekonomi (atau KDNK) dengan memisahkan tenaga (penawaran dan penggunaan tenaga) di Malaysia dengan menggunakan teknik-teknik siri masa. Penemuan yang utama bagi penawaran tenaga dari tesis ini adalah seperti berikut : *(1)* Hubungan jangka panjang telah dikesan dari penawaran minyak dan arang batu ke KDNK. *(2)* Hubungan jangka pendek satu arah wujud dari KDNK ke penawaran petroleum dan gas. *(3)* Keputusan dari ujian penguraian varians mencadangkan bahawa penawaran arang batu dan minyak adalah lebih penting kepada KDNK jika berbanding dengan penawaran tenaga lain. Bagi permintaan dan penggunaan tenaga, keputusan utama adalah: *(i)* hubungan dari gas dan CO_2 ke KDNK wujud dalam jangka panjang dan pendek. *(ii)* jangka pendek satu arah wujud dari elektrik ke CO_2. *(iii)* Keputusan dari ujian penguraian varians mencadangkan bahawa penggunaan minyak dan elektrik adalah lebih penting kepada KDNK di luar sampel.

ABSTRACT

DYNAMIC INTERACTION BETWEEN ECONOMIC GROWTH AND ENERGY IN MALAYSIA

By

TAN CHIANG CHING

This thesis attempts to investigate the causal relationship between economic growth (or GDP) and disaggregate energies (energy supply and consumption) in Malaysia by applying the time-series techniques. The major findings for energy supply extract from this thesis are as follows: *(1)* Long run causality was detected from oil and coal supply to GDP. *(2)* Short run unidirectional causality exists running from GDP to petroleum and gas supply. *(3)* The results of the variance decompositions suggest that coal and oil supply are relatively more important on GDP if compare to other energy supplies. As for energy consumption, the major findings are: *(i)* Causality relationship from gas and CO_2 to GDP exists in both the long and short run. *(ii)* Short run unidirectional causality exists running from electricity to CO_2. *(iii)* The results of the variance decompositions suggest that oil and electricity consumption are relatively more important on GDP beyond the sample.

Statement of Originality

The work described in this thesis, entitled
"**Dynamic Interaction between Economic Growth and Energy in Malaysia**"
is to the best of the author's knowledge that of the author except
where due reference is made.

(Date Submitted)

TAN CHIANG CHING
11021744

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CHAPTER ONE

INTRODUCTION

1.0 Introduction

Energy is a crucial factor of production as well as a key player in the production process (Stern, 2000). This is because energy can directly be used to manufacture a product from raw material to final product. In addition, Pokrovski (2003) also proposed that energy has been used as an external source to substitute labour input in technological processes. He also stated that energy is used as a value creating production factor. Hence, energy is the main factor of economic growth because much of production and consumption activities rely on energy as a basic input and the growth of industry area will essentially lead to an increase in energy consumption (Noor and Siddiqi, 2010).

1.1 Background of the Study

The International Energy Agency estimated that global energy consumption will increase by 53 per cent in 2030, with 70 per cent of the growth of demand coming from developing countries (Oh et al., 2010; Shaari et al., 2013). Malaysia, with a gross domestic product (GDP) of RM 765,965 million (Department of Statistics Malaysia, 2011) and real GDP growth of 7.2 per cent in 2010 (Bank Negara Malaysia, 2011), is one of the developing countries in Association of Southeast Asian Nations (ASEAN).

Malaysia was categorised as rich in natural resources such as forests and minerals in Southeast Asia. According to Energy Information Administration (EIA, 2013a), Malaysia was the second largest oil and natural gas producer in Southeast Asia as well as the second largest liquefied natural gas (LNG) exporter in the world after Qatar in 2012. In the case of oil reserves, Malaysia was the fifth highest in Asia-Pacific after China, India, Vietnam and Indonesia. Moreover, Malaysia also listed as one of the top thirty largest oil reserves in the world. Therefore, export of oil and natural gas are one of the main significant drivers of Malaysia's economy (Economic Planning Unit, 2010a; Central Intelligence Agency (CIA), 2010).

In 1985, Malaysian government had implemented the Industrialisation Plan, which incurred a structural shift from an agriculture-based to manufacturing and service-based economy. Due to the manufacturing and service-based economy in Malaysia, therefore Malaysia has high rates of energy consumption (Lean and Smyth, 2014b). As supported by Islam et al. (2009), Bari et al. (2012) and Lean and Smyth (2014b), the demand for energy in Malaysia had increased rapidly in the past three decades. This status is consistent with the energy database in Asia-Pacific Economic Cooperation (APEC), which stated that energy consumption had rose by about 531 per cent from 1980 to 2010. As a result, this figure had proved the rapid growth in energy demand in Malaysia.

Energy sources in Malaysia are originated from oil, coal, natural gas, and renewable energy. According to Malaysia Energy Information Hub (MEIH), Malaysian energy consumption of fossil fuels (oil, petroleum, natural gas and coal) was about 97 per cent of the total primary energy supply in 2011, which comprised of oil (31.1 per cent), petroleum (2.8 per cent), natural gas (45.1 per cent) and coal (18.6 per cent). Industrial, transport, agriculture, non-energy use, residential and commercial sector are the main sectors that contributed to energy consumption in Malaysia. According to National Energy Balance 2010 published by Energy Commission (2010), the transportation sector was the highest consumption in 2010, followed by the residential and commercial sector. The third largest consumer of energy in Malaysia was non-energy use then subsequently by industrial and agriculture sector. Hence, it can be concluded that fossil fuels was the main energy supply in Malaysia.

Therefore, electricity in Malaysia is largely generated from fossil fuels. About 95 per cent of electricity generation was derived from fossil fuels, energy from coal and natural gas (Shafie et al., 2011; APEC energy database) and this will caused to environmental degradation in Malaysia. It is because fossil fuels can resulted in the increase of carbon dioxide (CO_2) emissions that will triggered to global warming, water pollution, endanger flora and fauna, generate toxic wastes and many more (Oh et al., 2010; Bari et al., 2012). According to APEC energy database, the issue of CO_2 emissions by energy in Malaysia was indisputable and this had risen tremendously in the past three decades; by about 495 per cent from 1980 to 2010.

As a consequence, the government of Malaysia had started to focus on renewable energy since the Five Fuel Diversification Strategy 1999 was implemented. This policy was set up to reduce dependency on fossil fuels which was harmful to the environment. However, Malaysian government is still supporting few renewable energy projects such as Small Renewable Energy Programme (SREP) although the development in renewable energy is slow (Mohamed and Lee, 2006; Hashim and Ho, 2011).

1.2 Energy Policies in Malaysia[1]

The Malaysian government had formulated a number of energy policies and programmes on energy in the past, to ensure the long run reliability, sustainability and energy security for sustainable social-economic development in Malaysia.

Central Electricity Board (CED) was the first energy policy formed in Malaysia in 1949, and it was changed to the National Electricity Board (NEB) in 1965. After that, Petroleum Development Act 1974, which was constituted by Petroleum Nasional Berhad (PETRONAS) was implemented. And this act had impacted the industrial sector in that year. Later the National Petroleum Policy 1975, which was under the Third Malaysia Plan (1976-1980) was executed. The main objective of this policy was to utilise the efficiency of the resource for industrial development, as well as to control the management and operation of the industry. In other words, National Petroleum Policy 1975 was aimed to regulate the downstream industry.

Next, National Energy Policy 1979 was formulated in 1979 which was more significant than the previous energy policies in Malaysia. It had three primary objectives that were related to supply, utilisation and environment. The first objective focused on supply. It was aimed to ensure the provision of adequate, secure

[1] Refer to Mohamed and Lee (2006), Jalal and Bodger (2009) and Oh et al. (2010).

and cost effective energy supplies through the development of indigenous non-renewable and renewable energy resources via the least cost options and diversification of supply sources both from within and outside Malaysia. The second objective focused on utilisation. It was set up to promote the efficient utilisation of energy and to discourage wasteful and non-productive patterns of energy consumption. The last objective focused on the environment. It was intended to minimise the negative impacts of energy production, transportation, conversion, utilisation and consumption on the environment (Ministry of Energy, Green Technology and Water (KeTTHA), 2013a; GreenTech Malaysia, 2013).

There was a rapid increase in the production of crude oil in 1980 and National Depletion Policy was established to protect the exploitation of natural oil reserves. Subsequently, the Four Fuel Diversification Strategy 1981 was carried out in the next year. The main purpose of Four Fuel Diversification Strategy 1981 was to avoid over dependence on oil as the main energy resource in Malaysia. After the twice of global oil crisis and quantum leaps in prices in 1973 and 1979, Malaysia had learnt its lesson on highly dependency on one energy resource, which was oil. The government had targeted to develop more natural gas, coal and hydro in that policy.

In 1999, the Four Fuel Diversification Strategy was amended and became Five Fuel Diversification Strategy. Renewable energy was announced as the fifth fuel in the energy supply and a target of 5 per cent contribution towards the Malaysian electricity demand by year 2005 was fixed. Small Renewable Energy Programme (SREP) 2001 had facilitated the Five Fuel Diversification Strategy in achieving the goal. SREP aimed to support the renewable energy (fifth fuel resource) in development and utilisation. All these objectives can be found in the Third Outline Perspective Plan (OPP) 2001-2010 and the 8th Malaysia Plan (2001-2005).

One of the schemes in the 9th Malaysia Plan (2006-2010) was to intensify the energy efficiency in better utilisation of energy resources. Therefore, this had offset the energy challenge of the reliance on petroleum as more efforts were paid to integrate alternative fuels. Then, the National Green Technology Policy was launched in 2009 and it had four pillars. The first pillar was sought to attain energy independence and to promote efficient utilisation. The second pillar was to conserve and minimised the impact on the environment. The third pillar was to enhance the national economic development through the use of technology, while the last pillar was to improve the quality of life for all (Ministry of Energy, Green Technology and Water (KeTTHA), 2013b).

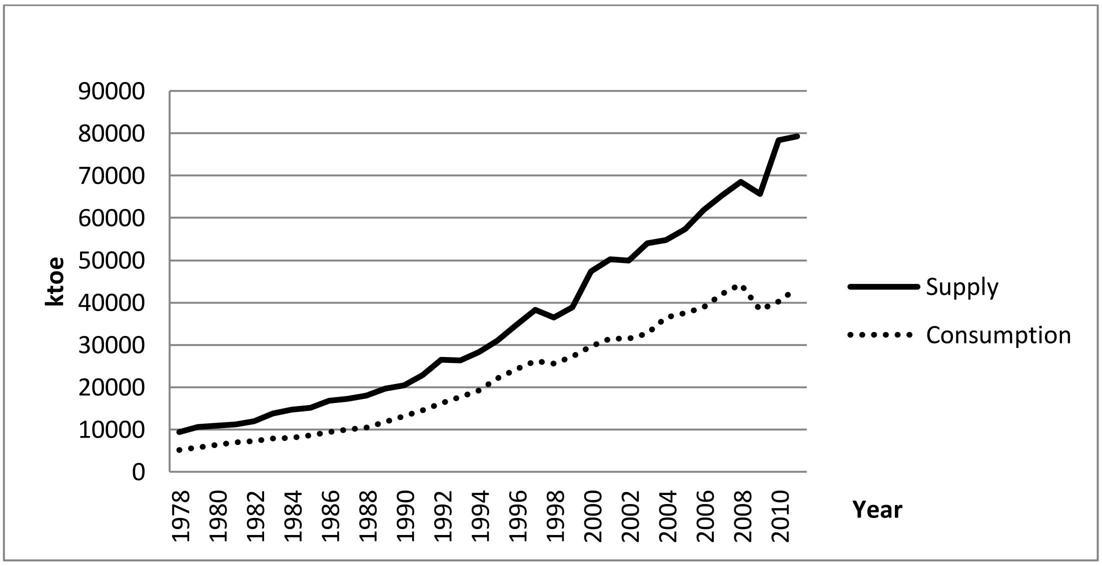
In addition, the New Energy Policy (2011-2015) which was under 10th Malaysia Plan (2011-2015) emphasised on energy security, economic efficiency and environmental and social considerations. It was intended to enhance alternative resources such as hydro, coal and liquefied natural gas by 2015. After National Green Technology Policy 2009, the New Energy Policy also focused on five strategic pillars: which were to secure and manage reliable energy supply, measures to encourage energy efficiency, adoption of market-based energy pricing, strengthen in governance and managing change (Economic Planning Unit, 2010b).

Table 1.1: Chronology of Energy Policies in Malaysia

Year	Energy Policy
1949	Central Electricity Board (CED) implemented
1965	CED change to National Electricity Board (NEB)
1974	Petroleum Development Act 1974, vested on PETRONAS • PETRONAS was responsible to explore, develop, refine and produce petroleum a resource in Malaysia
1975	National Petroleum Policy 1975 • Under 3rd Malaysia Plan (1976 - 1980) • Main objective: to utilise the efficiency, control the management and operation of the industry • This policy also aimed to regulate downstream industry
1979	National Energy Policy 1979 • 3 primary objectives: supply, utilisation and environment protection
1980	National Depletion Policy
1981	Four Fuel Diversification Strategy 1981 • Main objective: to avoid over dependence on oil as the main energy resources
1999	Four Fuel Diversification Strategy was amended to become Five Fuel Diversification Strategy • Fifth fuel resources: renewable energy
2001	Small Renewable Energy Programme (SREP) • Under Special Committee on Renewable Energy • Main purpose: helped the Five Fuel Diversification Strategy to achieve the goal
2006-2010	9th Malaysia Plan • Emphasis intensified for energy efficiency on better utilisation of energy resources
2009	National Green Technology Policy • This policy had 4 pillars
2011-2015	New Energy Policy • Under 10th Malaysia Plan • Emphasise energy security, economic efficiency and environmental and social considerations • Focuses on 5 strategic pillars

1.3 Overview of Energy in Malaysia

Figure 1.1: Energy Supply and Energy Consumption in Malaysia, 1978-2011

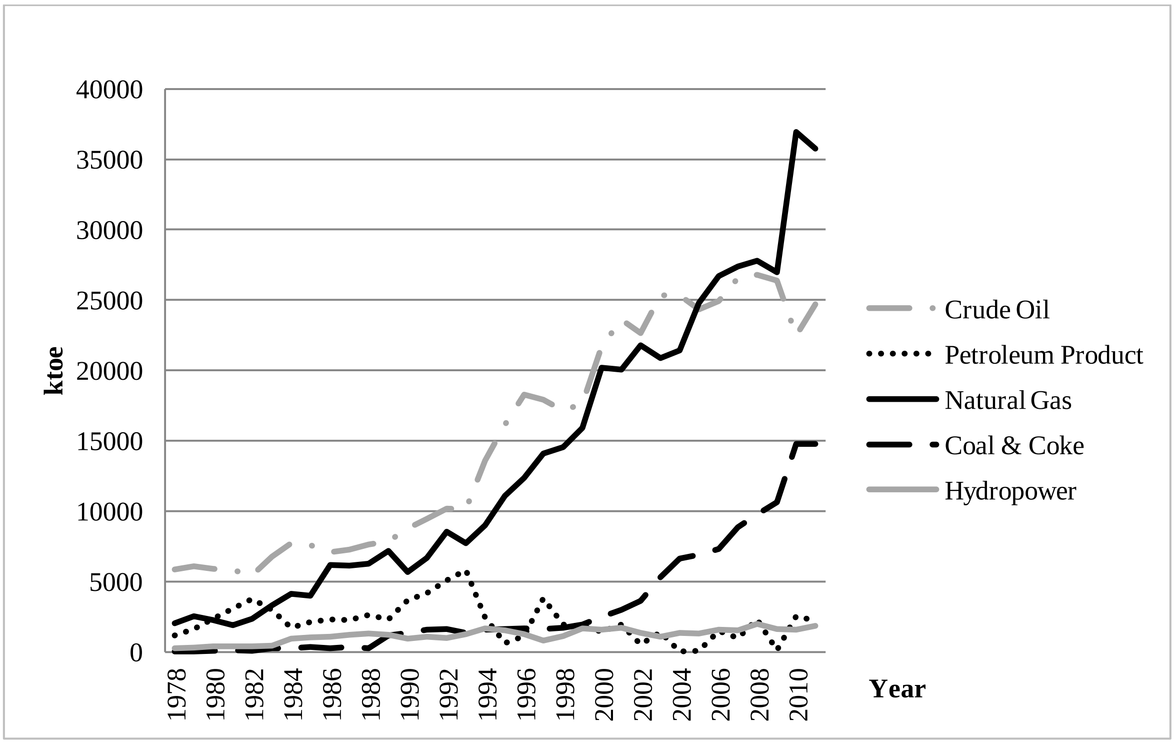


Source: Statistics of Energy Balance, Malaysian Energy Information Hub (MEIH).

Figure 1.1 showed the trend of energy supply and energy consumption in Malaysia from 1978 to 2011. Energy supply and energy consumption as well as other energy resources were measured in kilo tonnes of oil equivalent (ktoe). There was a rapid increase in energy supply and consumption in Malaysia which was about 750 per cent from 1978 to 2011. Since Malaysia had moved the country's economic focus from agriculture to manufacturing and service-based, so the increase in economic growth had led to high rate of energy supply and demand since mid 1980s. Currently, energy sources in Malaysia mainly originate from oil, coal, petroleum, natural gas, and renewable energy (including hydroelectric energy).

1.3.1 Energy Supply

Figure 1.2: Energy Supply by Fuel Type in Malaysia, 1978-2011



Source: Statistics of Energy Balance, Malaysian Energy Information Hub (MEIH).

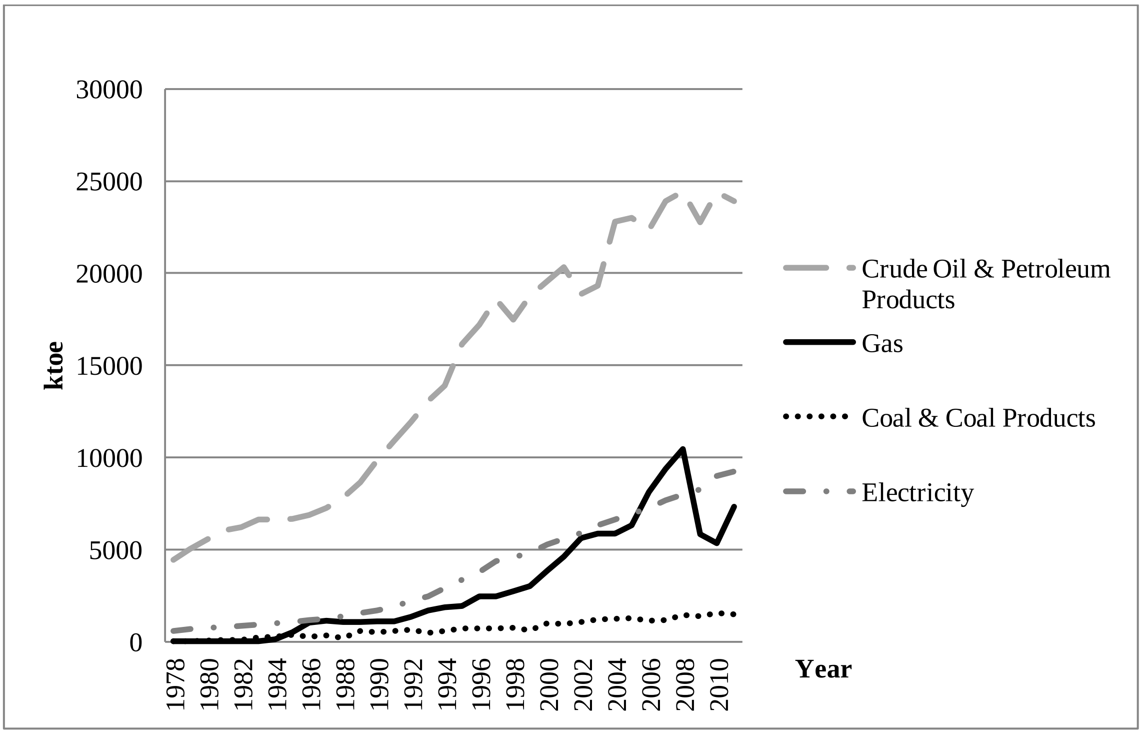
Figure 1.2 presented the trends of energy supply by fuel types, which are crude oil, petroleum products, natural gas, coal and coke and hydropower in Malaysia from 1978 to 2011. It showed that overall energy supply by fuel types were increasing, except for petroleum products. The highest peak for petroleum products in Malaysia was on 1993, but it had fluctuated in the later time. Although biodiesel was one of the new renewable energy sources promoted by the Malaysia government, the development of biodiesel was still in its early stage. Nevertheless, this had proved that Malaysia had a very good start in the utilisation of renewable energy instead of hydropower.

Moreover, the highest energy supplier in the country in 2011 was natural gas, which was 45.1 per cent of the total energy supply in Malaysia in that same year. This was followed by crude oil, 31.1 per cent; and coal and coke with 18.6 per cent. Other than that, petroleum products and hydropower had about the same percentage of the total energy supply, which were 2.8 per cent and 2.3 per cent, respectively.

Furthermore, hydropower and crude oil had positive growth in 2011 compared to 2010. Total hydropower production registered a big growth in 2011, which was 17.3 per cent, compared to 2010. Crude oil had only increased by 9.7 per cent in 2011 compared to 2010. Besides that, Petroleum products had a slump of 11.8 per cent in 2011. Natural gas and coal and coke supply productions too experienced a slight decrease of less than 4 per cent in 2011 compared to 2010.

1.3.2 Energy Consumption

Figure 1.3: Energy Consumption by Fuel Type in Malaysia, 1978-2011



Source: Statistics of Final Energy Consumption, APEC Energy Database.

Figure 1.3 demonstrated the trends of energy consumption by fuel types, which are crude oil and petroleum products, gas, coal and coke products and electricity in Malaysia from 1978 until 2011. It had clearly showed that the overall energy consumption had been increasing constantly.

According to APEC energy database, the highest energy consumption by fuel types in 2011 was crude oil and petroleum products with the contribution of almost 57 per cent of total energy consumption in Malaysia. Next, was electricity with the contribution about 22 per cent and it was followed by gas with nearly 18 per cent of total energy consumption in 2011. The lowest energy consumption was coal and coal products, which only contributed nearly 4 per cent of total energy consumption in Malaysia in 2011.

According to APEC Energy Statistics 2011, published by The Energy Data and Modelling Center, The Institute of Energy Economics Japan (2013), the transport sector was the largest consumer of energy, at about 36 per cent of total energy consumption in 2011. The next was the industrial sector, contributing about 27 per cent of total energy consumption. By comparison, commerce and public services (14 per cent), residential (6 per cent) and other sectors (16 per cent) were relatively low.

This was due to the switch of used of energy resources in the past where Malaysia was relied on oil as main the energy resources in the early of 1980s then it was followed by the shift economic focus from agriculture-based to manufacturing and service-based in 1985. The dependence on oil as the primary energy resources was only removed after the implementation of Four Fuel Diversification Strategy. Consequently, this has caused to the rapid growth in the consumption of gas and coal (Lean and Smyth, 2014a, 2014b).

There was a significant different in the comparison of 1985 and 2011. The consumption of oil in 1985 was made up 77 per cent of total energy consumption, whereas in 2011, the consumption of oil only made up 57 per cent of total energy consumption. This had proved that consumption of oil had dropped about 20 per cent of total energy consumption in Malaysia between 1985 and 2011. Moreover, consumption of gas had rose nearly 12 per cent, from only 6 per cent in 1985 to nearly 18 per cent in 2011 of total energy consumption.

Natural gas in Malaysia was abundant and it had become one of the main energy contributors since early 2000's. Oh et al. (2010) indicated that natural gas still able to contribute to Malaysia's energy for the next 36 years as compared to oil which will only last for around 20 years. On the other hand, Mohamed and Lee (2006) stated that natural gas still able to contribute to Malaysia's energy for the next 80 years as compared to about 10 years for oil. Although both studies had different time period for natural gas's life span, all of them testified that natural gas can be maintained as one of the main energy resources in Malaysia for at least 36 years.

Coal was another abundant source that had low and stable price (Mohamed and Lee, 2006; Oh et al., 2010). States that consist of coal sources in Malaysia includes Selangor, Perak, Perlis, Sarawak and Sabah. Most of the coal was produced in Sarawak. Although Malaysia had increase the usage of coal as one of the main energy resources, the production of coal was relatively small as compared to its demand (Mohamed and Lee, 2006). This will eventually cause Malaysia to import coal from other countries, especially from Australia, Indonesia, China and South Africa.

The main reason for Malaysia to change its energy resources from oil to hydroelectric and renewable energy was that fossil fuels (oil, natural gas and coal) had been rapidly depleting whereas other reasons were global warming as well as price volatility with oil import. For instance, the fossil fuels that were being used to generate electricity will cause to the increase of CO_2 emissions (Bari et al., 2012). In other words, it means that the greater the consumption of electricity, the greater the contribution to emission of CO_2.

Due to the strong dependency on fossil fuels in the past that had caused to pollution issues, the government had initiated many incentives to support the reliance on renewable energy in these few years. For example, SREP, Biomass Power Generation and Demonstration (BioGen) Project, Malaysian Building Integrated Photovoltaic Technology Application Project (MBIPV) and other programmes had been commenced to support the reliance on renewable energy (Mustapa et al., 2010).

1.4 Problem Statement

The issue of security in energy supply has become a primary concern for countries worldwide since the occurrence of oil crisis in 1973 and quantum leaps in price in 1979. Such insecurity of energy supply has resulted in the search for alternate energy sources, especially cheap domestic energy supply as the fundamental behind energy policy of many countries (Toth and Rogner, 2006). Apart from that, diversification of energy sources as well as finding a stable and safe energy supply have become one of the main concerns of energy policy. In this context, energy security has become an increasing important issue that have received global attention.

Malaysia of course, has focused its attention on this issue as well. In Malaysia, high economic growth has been on the back of increasing energy consumption where Malaysia is heavily dependent on fossil fuels. According to MEIH, fossil fuels (crude oil, petroleum, natural gas, and coal and coke) contributed about 97 per cent of the total primary energy supply in 2011. In the future, fossil fuels will be totally consumed and hence, Malaysia which is heavily dependent on fossil fuels will encounter obstacles in its future development. This situation has foster Malaysia's need to find an alternative energy source to replace the fossil fuels.

In 2011, around 79 per cent of Malaysia primary energy supply comes from crude oil and petroleum products as well as natural gas. According to Energy Transformation Programme annual report 2013 (PEMANDU, 2014), Malaysia is endowed with conventional energy resources such as oil and gas, and other renewable sources and these energy sources are currently contributing roughly 20 per cent to Malaysian economy in 2013. Unfortunately, Malaysia's proven oil and natural gas reserves are projected to be depleted in the next 19 and 33 years, respectively if no alternative measures are found to sustain the reserves (Bekhet and Yusof, 2009). Similarly, Oh et al. (2010) also documented that Malaysia will become a net oil importer country by year 2030.

In addition, while Malaysia has limited domestic coal reserves, Malaysia has only able to produce about 12 per cent of its total coal consumption in 2012 (EIA, 2013a). At the same time, Malaysia is much dependent on imported coal from Indonesia, which is used mainly for its electricity output. In view that Malaysia is a primary coal user yet it is facing unsustainable domestic supply in coal, this situation has resulted in insecurity issue for coal.

On the other hand, hydropower is one of the major renewable energies that contribute in Malaysia's energy sector. Even though renewable energy is one of the alternative energy resources, the progress has been slow and it is still in the early stage in Malaysia (Mohamed and Lee, 2006; Oh et al., 2010; Hashim and Ho, 2011). Such situation can be observed in which hydropower only contributed 2 per cent of its primary energy supply in 2011. The slow progress has risen the need to determine the contribution of renewable energy, hydropower specifically in the development of Malaysian economy.

Furthermore, the increasing pollution level in Malaysia has received attention in which researchers such as Lean and Smyth (2014a) has stated that Malaysia has one of the highest rates of greenhouse gas (GHG) emissions in the world. At the same time, EIA (2013b) also has reported that Malaysia will continue to rely on fossil fuels to meet the growth in its energy demand and as such, its emerging economy is expected to increase the CO_2 emissions[2]. In addition, Shamsuddin (2012) stated that Malaysia's GHG emissions are expected to increase 74 per cent from 2005 to 2020. In other words, Malaysia is currently facing the challenge of increasing pollution level in the trade off of achieving economy growth.

Therefore, appreciating the causal nexus between disaggregated energy and economic growth as well as CO_2 emissions is important in the sense of obtaining smooth economic growth and it will allow Malaysian energy sector to efficiently use its energy all the time. In other words, Malaysia should endeavour to uncover the causal relationship between disaggregated energy and economic growth as well as CO_2 emissions to make appropriate energy policy to proactively cope with increasing energy demand accompanying rapid economic growth and at the same time reduce CO_2 emissions. This task has become one of the most important ones for Malaysia in the present and future.

[2] Dependence on fossil fuel consumption has caused serious concerns about its effects on the environment, especially CO_2 emissions. Burning of fossil fuels for energy use will increase GHG emissions.

1.5 Objectives of the Study

The general objective of this study is to investigate the relationship between *(1)* energy supply by fuel types[3] and economic growth, *(2)* energy consumption by fuel types[4] and economic growth from 1978 until 2010 for energy supply and from 1980 until 2010 for energy consumption in Malaysia.

The specific objectives of this study are as following:

Energy Supply

i. To determine the possible existence of a long run relationship between the types of energy supply and economic growth.
ii. To examine the existence and different direction of causation in the short and long run regarding the types of energy supply and economic growth (or GDP).

Energy Supply with Pollutant Variable (CO_2 Emissions)

i. To determine the possible existence of a long run relationship between the types of energy supply, economic growth and CO_2 emissions by energy.
ii. To examine the existence and different direction of causation in the short and long run regarding the types of energy supply, economic growth (or GDP) and CO_2 emissions by energy in Malaysia.

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[3] The energy supply by fuel types under study are crude oil, petroleum products, natural gas, coal and coke, and hydropower.
[4] The energy consumption by fuel types under study are oil and petroleum products, natural gas, coal and coke, and electricity.

Energy Consumption

i. To determine the possible existence of a long run relationship between the types of energy consumption, economic growth and CO_2 emissions by energy.

ii. To examine the existence and different direction of causation in the short and long run regarding the types of energy consumption, economic growth (or GDP) and CO_2 emissions by energy in Malaysia.

1.6 Significance of the Study

The study is to focus on the relationship between economic growth and disaggregate energies (energy supply and consumption) in Malaysia. This study will help to identify whether Malaysia is an energy-dependent country (GDP leads to energy) or vice-versa. The results of this study will help Malaysia to efficiently draft future policies.

In order to meet the increasing demand, energy supply infrastructure will need to be continuously developed to ensure its long term energy security and to intensify energy efficiency initiatives. Vision 2020 was introduced by the former Prime Minister of Malaysia, Tun Dr. Mahathir bin Mohamad that aimed to achieve a self-sufficient industrialized nation by the year 2020. Vision 2020 is another 6 years from now and the Malaysian government is developing its energy sector every year, but the strain caused by the rise in energy demand outweighs the benefits brought by these improvements in Malaysia (Mustapa et al., 2010). Besides, high consumption of energy resources especially fossil fuels can have a negative impact on the environmental quality (CO_2 emissions). High level of CO_2 emissions may exert negative externalities to the economy, such as bringing down the tourism sector and also affecting human health thus reducing productivity in Malaysia (Chebbi, 2009; Pao and Tsai, 2010; Alkhathlan and Javid, 2013).

Vision 2020 suggests that the industrial sector will be central to our economy, so the industrial sector will be an important consumer of energy in Malaysia (Lean and Smyth, 2014b). Likewise Gan and Li (2008) mentioned that Malaysia's energy demand is expected to triple in 2030. However energy security supplies, energy shortage and energy prices have become the top issues in the energy sector. So, the Malaysian government must solve these energy issues as it works towards Vision 2020.

In the past, most previous studies were concerned about the relationship between economic growth and total energy or aggregated energy in Malaysia (Masih and Masih, 1996a; Ang, 2008; Chiou-Wei et al., 2008; Chontanawat et al., 2008; Narayan et al., 2010; Narayan and Popp, 2012; Islam et al., 2013; Tang and Tan, 2014). But aggregate energy data has its own disadvantage especially in formulating government policies. The main disadvantage for aggregate energy data is that it is not possible to identify the relationship of specific energy types on economic growth (Sari et al., 2008; Lean and Smyth, 2014a).

In contrast, some recent studies that have examined the relationship between energy and economic growth in multi-country studies, but in this study only focus on a specific country, which is Malaysia. Malaysia is an Asian success story in terms of its economy and is an interesting case for energy study. It is hoped the findings of this study will help Malaysia to formulate policies effective to the country.

Furthermore, the findings from this study will also provide more information on the existing knowledge on Malaysian energy and their economic growth. Assessing the relationships between energy and GDP will also help the economy experts to be able to come up with new plans and strategies, such as new energy plans, to boost the present national income. These will be useful to academicians, political economists and Malaysia Ministry of Energy, Green Technology and Water as reference.

1.7 Scope of the Study

In this study, we examine the relationship between energy supply and economic growth as well as energy consumption and economic growth in Malaysia. The background of energy and economic growth in Malaysia are presented in Chapter One, meanwhile the findings from pass studies will be presented in Chapter Two. Chapter Three includes the data description and methodological analysis. Chapter Four provides the empirical results and discussions. Lastly, Chapter Five concludes the study with the summary, policy implications and the limitations involved.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

Many researchers have argued about the causal relationship between energy consumption and economic growth after the study made by Kraft and Kraft (1978) who initiated the idea to examine the causal relationship between energy consumption and economic growth in the United States (US). Important policy implications have resulted based on the causal relationship between energy consumption and economic growth. Moreover, the causality relationship is able to provide information to help formulate energy supply policies. For these reasons, many researchers have continued to study the relationship between the variables by using different methodologies, countries and so forth. But, the results of the previous studies are mixed in which some studies found bidirectional causality relationship, no causality relationship, and unidirectional causality that run from energy consumption and energy supply to economic growth.

This chapter reviews relevant empirical evidences from numerous literatures as a guideline in order to determine the suitable methodology and sample data that can be employed to identify the relationship between energy and economic growth in Malaysia.

2.1 Studies on Energy Supply and Economic Growth

The causal relationship between energy supply and economic growth has been rarely investigated in the economic literature. Although there had seldom been studies about the relationship between energy supply and economic growth, the results of some previous studies have shown some dissimilarity outcomes.

Morimoto and Hope (2004) applied standard ordinary least square (OLS) to examine the impact of electricity supply on economic growth for Sri Lanka. The data used in this study was from 1954 to 1997. They found that the change in electricity supply had a significant impact on the change in real gross domestic product (GDP). Increase of electricity supply will takes some time to have its full effect on GDP growth.

Another study was carried out by Yoo and Kim (2006) about the relationship between electricity generation and economic growth in Indonesia. The data that they used was collected from 1971 until 2002. The methodologies that they applied were Engle Granger (EG), Johansen cointegration and Hsiao's version of Granger causality test. The result implied that there was no long run relationship between electricity generation and economic growth. Then, Hsiao's Granger causality indicated that there was unidirectional causality relationship from economic growth to electricity generation. They discovered that the economy in Indonesia was not affected in spite of increasing or decreasing electricity generation.

Ghosh (2009) examined the causal relationship between electricity supply, employment and real GDP in India. He applied Auto-Regressive Distributive Lag (ARDL) bounds testing approach of cointegration and found that there was long run relationship between electricity supply, employment and GDP. He also found that there was unidirectional long run and short run causality relationship from real GDP and electricity supply to employment without any feedback effect. In short run, there is unidirectional causality relationship between real GDP to electricity supply. Ghosh (2009) suggested that India can consider renovation and modernisation of existing power plants to increase energy supply for future power generation.

Besides that, Lean and Smyth (2010b) used the electricity generation data of Malaysia from 1970 to 2008 to investigate the relationship between economy growth and electricity generation and found that there is a unidirectional Granger causality running from economic growth to electricity generation. As such, their finding indicates that energy conservation policies, such as reducing the wastage of electricity and curtail generation can be implemented without having an adverse effect on Malaysia’s economic growth.

Recently, Ubi et al. (2012) also used the OLS and Johansen cointegration test to analyse the determinants of electricity in Nigeria, from 1970 to 2009. They found that a long run equilibrium relationship existed between electricity supply and other variables in the model. Additionally, technology, government funding and the level of power lost were statistically significant (the most reliable) determinants of electricity supply in Nigeria. Even though the study of Morimoto and Hope (2004) and Ubi et al. (2012) applied the same methodology, but they discovered different empirical findings due to different variables, time period and country adopted in their study. Table 2.1 shows the summary of literature reviews on the relationship of energy supply and economic growth.

Table 2.1: Summary of Empirical Studies on Energy Supply and Economic Growth

Author(s) / Year	Period	Country	Methodology	Main Finding
Morimoto and Hope (2004)	1954-1997	Sri Lanka	Standard OLS	Electricity supply had significant impact on real GDP
Yoo and Kim (2006)	1971-2002	Indonesia	EG, Johansen cointegration, Hsiao's Granger causality	Real GDP --- Electricity supply (in long run) Real GDP → Electricity supply
Ghosh (2009)	1970/71-2005/06	India	ARDL bound test	Real GDP and electricity supply→ employment (in long and short run) Real GDP → electricity supply (in short run)
Lean and Smyth (2010b)	1970-2008	Malaysia	ARDL, TYDL Granger causality	GDP → Electricity generation
Ubi et al. (2012)	1970-2009	Nigeria	OLS	Technology, government funding and the level of power lost were significant determinants of electricity supply

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EG = Engle-Granger, ARDL = autoregressive distributed lag, TYDL = Toda-Yamamoto-Dolado-Lutkephol, OLS = ordinary least square.

2.2 Energy Consumption and Economic Growth in Malaysia

From the pioneering work about energy consumption and economic growth in US from Kraft and Kraft (1978), nowadays there is a large literature on the relationship between energy consumption and economic growth. Following this initial framework, many researchers have extended the analysis to other developed or developing countries, even for a group of country. Therefore, studies about energy consumption and economic growth in Malaysia are also not an exception from previous literatures. Previous Malaysia studies can provide clear and distinct energy policy to Malaysia. However, the results of the previous studies have shown some contradictory outcomes occasionally, even in the same country.

In examining the energy/electricity consumption in Malaysia, Tang (2009) stated that electricity consumption function is associated with income, foreign direct investment (FDI) and population. Tang (2009) discovered that on one hand, there is a unidirectional causality running from population growth to electricity consumption and on the other hand, population growth and income is found to Granger cause each other. In the long run, there is a Granger causality relationship running from income, FDI and population to electricity consumption. According to these findings, Tang (2009) suggested that Malaysia should imply energy saving policies that may have an inverse effect on economic growth as the results indicates that Malaysia is an energy dependent country.

Similar with Tang (2009), Chandran et al. (2010) also revealed that had Malaysia is an energy dependent country. Chandran et al. (2010) used electricity consumption, real GDP as well as price their model estimation in which they found that electricity consumption, real GDP and price have a long run relationship. Other than that, there is a unidirectional causality running from electricity consumption to economic growth. As such, Chandran et al. (2010) suggested that Malaysia can imply any conservation policies or else, a shock to energy supply will have an adverse effect on economic growth.

Nanthakumar and Subramaniam (2010) conducted a study on energy consumption and economic performances in Malaysia, by utilising data for the period 1971 to 2008. The main finding from error correction model (ECM) representation of the ARDL indicated that a bidirectional relationship existed between energy consumption and Malaysian's economic performance. They proposed to the Malaysian government on the use of an alternative energy, especially renewable energy to replace fossil fuels in future because unstable price of fossil fuel may be harmful to Malaysia's economy.

Likewise, Aziz (2011) examined the causal relationship between energy consumption and economic growth in Malaysia. Aziz (2011) employed Johansen cointegration test and vector error correction model (VECM) Granger causality test in the study. Over the period 1970 to 2009, Aziz (2011) found unidirectional causality running from economic growth to energy consumption in both the short and long run. The empirical finding suggests that energy conservation policies should be implemented in Malaysia.

Meanwhile, both Nanthakumar and Subramaniam (2010) as well as Islam et al. (2013) found out that there was bidirectional causality between economic growth and energy consumption. Islam et al. (2013) utilised ARDL bound test and VECM

Granger causality test in their study. The study period covered from 1971 to 2009. Islam et al. (2013) suggested that Malaysia needed to invest in renewable energy sources in the long run.

Besides that, Shaari et al. (2013) explored the relationship between energy consumption and economic growth in Malaysia over from 1980 to 2010 by using Johansen cointegration and Granger causality test. A Johansen cointegration test showed that a long run relationship between economic growth and energy consumption (electricity, oil, gas and coal consumption) existed in their study. Results of Granger causality illustrated that a unidirectional causality from economic growth to electricity consumption, as well as from gas consumption to economic growth existed in the short run. Therefore, the empirical findings suggested that a reduction in Malaysia's gas utilisation will harm the Malaysian economic growth. Moreover, green technology needed to be developed, suggested by Shaari et al. (2013).

Furthermore, in another study published by Tang and Tan (2013) which included economic growth and electricity consumption in their model, and at the same time they also comprised of technology innovation and energy prices. They found that income had a positive effect on electricity, but energy price and technology innovation had a negative impact on electricity consumption in the long run. Moreover, there was bidirectional causality running between electricity consumption and income in both the short and long run. Unidirectional causality running from technology innovation to income and electricity consumption also existed in their study. The empirical results advised that increase investment in electricity infrastructure can ensure sufficient supply of electricity for Malaysia's economy.

Unlike previous studies, Lean and Smyth (2014a) investigated the relationship between disaggregated energy consumption by fuel type and economic growth in Malaysia from 1980 to 2011. They utilized Lagrange multiplier (LM) unit root, ARDL bound test and unrestricted error correction model (UECM) to analysis the long run and short run relationships between the variables. The main findings of their study are that diesel is the major contributor to economic growth in the long run. Diesel also is the major cause of greenhouse gas (GHG) emissions in Malaysia. In the short run, diesel, fuel oil, kerosene, liquefied petroleum gas (LPG) and motor petrol have a positive effect on Malaysian GDP. The empirical results suggest that Malaysia can replace diesel and motor petrol with cleaner biodiesel fuel with less effect towards the Malaysia's economy.

Moreover, the study done by Park and Yoo (2014) focused on oil consumption and economic growth in Malaysia, starting from 1965 to 2011. The overall results imply that there is bidirectional causality between oil consumption and economic growth, in both long run and short run. The empirical results suggest that Malaysia should endeavour to overcome the constraints on oil consumption.

As a conclusion from the studies, there are different causality results between GDP and energy consumption. These conflicting empirical findings might be caused by different time periods, methodologies, even in the same country (Malaysia). Table 2.2 shows the summary of literature reviews based on the relationship of energy consumption and economic growth in Malaysia.

Table 2.2: Summary of Empirical Studies on Energy Consumption and Economic Growth in Malaysia

Author(s) / Year	Period	Country	Methodology	Causality Relationship
Tang (2008)	1970-2005	Malaysia	ARDL, ECM, Granger causality	GDP, FDI, POP → EC (long run)
Chandran et al. (2010)	1971-2003	Malaysia	ARDL, Granger causality	GDP ← EC
Nanthakumar and Subramaniam (2010)	1971-2008	Malaysia	ARDL, ECM	GDP ↔ EC
Aziz (2011)	1970-2009	Malaysia	Johansen cointegration, VECM, Granger causality	GDP → EC (short & long run)
Islam et al. (2013)	1971-2009	Malaysia	ARDL, VECM, Granger causality	GDP ↔ EC (short & long run)
Shaari et al. (2013)	1980-2010	Malaysia	Johansen cointegration, Granger causality	GDP → electricity (short run) GDP ← gas (short run)
Tang and Tan (2013)	1970-2009	Malaysia	ARDL, Granger causality	GDP ↔ electricity consumption (short & long run)
Lean and Smyth (2014a)	1980-2011	Malaysia	LM unit root, ARDL, UECM	GDP ← diesel (long run) GDP ← diesel, fuel oil, kerosene, LPG & motor petrol (short run)
Park and Yoo (2014)	1965-2011	Malaysia	Johansen cointegration, ECM, Granger causality	GDP ↔ oil (short & long run)

Notes: GDP → EC means that the causality runs from economic growth to energy consumption. GDP ← EC means that the causality runs from energy consumption to economic growth. GDP ↔ EC means that bidirectional causality exists between economic growth and energy consumption. GDP --- EC means that no causality exists between economic growth and energy consumption. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy/electricity consumption, FDI = foreign direct investment, POP = population, VECM = vector error correction model, ECM = error correction model, UECM = unrestricted error correction model, ARDL = autoregressive distributed lag, LM unit root = Lagrange multiplier unit root.

2.3 Country-specific Studies on Energy Consumption and Economic Growth

Country-specific causality study between energy consumption and economic growth can provide clear and distinct energy policies for the respective country. However, the results of the previous studies have shown some contradictory outcomes occasionally, even in the same country. For example, Kraft and Kraft (1978) who were the pioneers in the study of the causal relationship between energy consumption and economic growth in US discovered that there was unidirectional causality running from economic growth to energy consumption. Meanwhile, Stern (2000) also conducted a study of the causal relationship between energy consumption and economic growth in US. The main finding was intended to prove that there was a unidirectional causal relationship from energy consumption to economic growth. However, the result was not consistent with Kraft and Kraft (1978) claims even though both studies were conducted at the same country, US.

In earlier studies from Stern (2000), Cheng (1998) investigated the relationship between energy consumption and economic growth, with additional variables, namely employment and capital in Japan. Cheng (1998) used Hsiao's Granger causality from 1952 to 1995 to examine these variables in Japan. In this study, Cheng (1998) found that there was unidirectional causality running from economic growth to energy consumption. This finding was consistent with the pioneer study of Kraft and Kraft (1978) even though different countries were employed.

Aqeel and Butt (2001) carried out a study to examine the causal relationship between energy consumption and economic activity in Pakistan, more specifically in economic growth. The relevant data were available for the period 1955-1956 to 1995-1996. The finding from cointegration and Hsiao's version of Granger causality indicated that economic growth causes to total energy consumption. On the other hand, they also found that there was a unidirectional causal relationship from economic growth to petroleum consumption. However, there was no any causality relationship between economic growth and gas consumption. Though, they indicated that there is a unidirectional causal relationship from electricity consumption to economic growth. They suggest that energy growth policy, especially for gas and electricity consumption, should be adopted to stimulate economic growth in Pakistan.

Besides that, Soytas et al. (2001) carried out a study to test the relationship of energy consumption and GDP in Turkey. The data from 1960-1995 were utilised to present more tough analysis about relationship between energy consumption and economic growth. The finding from Johansen-Juselius cointegration revealed that there is a long run relationship between GDP and energy consumption in Turkey. VECM tests found that the energy consumption has effects on income in the long and short run. So, Soytas et al. (2001) has concluded that there was a unidirectional causality relationship from energy consumption to GDP in Turkey. It means that the energy consumption will positively affect GDP. They suggested that energy conservation may harm to the economic growth in the long run.

Chang, Fang and Wen (2001) conducted a study on the relationship between energy consumption and output for Taiwan. The data that they used was from period January 1982 until November 1997. Johansen-Juselius cointegration test indicated there that the long run neutrality of VECM Granger causality analysis energy consumption with either output or employment does not hold for Taiwan. The finding showed that there was a unidirectional causality relationship running from energy consumption to output. The variance decomposition analysis and impulse response function suggested that energy consumption appeared to have led to output growth in Taiwan. So, the result of variance decomposition analysis and impulse response function was support by Granger causality test.

Moreover, Paul and Bhattacharya (2004) applied EG and Johansen cointegration as well as standard Granger test to examine the casual relation between energy consumption and economic growth in India, from 1950 to 1996. They found that a unidirectional causality ran from economic growth to energy consumption in the long run. Therefore, a different causality running existed in the short run, which was from energy consumption to economic growth.

Lee and Chang (2005) carried out a study that used the aggregate and disaggregate energy consumption and economic growth with structure breaks in Taiwan, by using data from 1954-2003. They adopted Johansen cointegration test and Granger causality. Bidirectional causal linkage exists between GDP and total energy consumption as well as GDP and coal consumption. However, there was a unidirectional causality from oil consumption, gas consumption and electricity consumption to GDP. The results showed that energy acted as an engine of economic growth in the long run and energy conservation may harm economic growth. Besides that, the cointegration between energy consumption and GDP was unstable and some economic events may have affected the stability. Lee and Chang (2005) found that there were structural breakpoints in various GDP-energy consumptions match compatibly with critical economic incidents of Taiwan.

Analysis of energy consumption by sector in Turkey was carried out by Jobert and Karanfil (2007). In this study, researchers were testing the causal relationship between energy consumption and income in two ways, which was studied at the aggregate level and focused on the industrial sector. Jobert and Karanfil (2007) used data from 1960-2003 and used the method of notion Granger causality and the notion of instantaneous (or contemporaneous) causality. The finding from cointegration and Granger causality tests were investigated and it was found that there was no stationary linear cointegrating relationship between energy consumption and income. However, the finding also showed that in the long run, income and energy consumption appeared to be neutral with respect to each other both at the aggregate and at the industrial level. By the instantaneous (or contemporaneous) causality, Jobert and Karanfil (2007) found that there was strong evidence of causality. It meant that contemporaneous values of energy consumption and income were collected. The researchers concluded that energy conservation policies were necessary for environmental concerns. The empirical results showed that such policies would not encumber economic growth in the long term.

In a similar study to Soytas et al. (2001) and Jobert and Karanfil (2007), Lise and Montfort (2007) tested the cointegration relationship between energy consumption and economic growth in Turkey. They used annual data from 1970-2003. The finding from cointegration test indicated that energy consumption and GDP were cointegrated. This meant that there was a long run relationship between energy consumption and GDP, which was significant indication for Granger causality. Therefore, the finding from Granger causality found that there was a unidirectional causality relationship from GDP to energy consumption without feedback. This demonstrated that energy saving would not harm the economic growth of Turkey. Lise and Montfort (2007) suggested energy consumption will keep on growing as long as the economy grows in Turkey.

Furthermore, Zamani (2007) studied the causal relationship between economic growth and aggregate and disaggregate energy consumption in Iran from 1967 until 2003. Zamani (2007) utilised the method of Johansen cointegration and ECM to study this research. In this research, there was unidirectional causality running from economic growth to total energy consumption in both the short and long run. Additionally, bidirectional causality between GDP and gas consumption as well as GDP and petroleum consumption also existed in the long run. In the short run, there was unidirectional causality running from GDP to petroleum consumption. The empirical findings suggested that Iran needed to increase the investment in energy sector especially for petroleum in the future.

In the case of Turkey again, Erdal et al. (2008) carried out a study on the relationship between primary energy consumption and economic growth from 1970 to 2006. The findings from Johansen cointegration and Pairwise Granger causality test showed that there was bidirectional causality between energy consumption and economic growth. At the end, they advocated that Turkey should reduce the country's dependency on external energy sources. Environmental factors also had to be taken into account should the policy implemented by Turkey's government.

In addition, Olusegun (2008) carried on a study to test the relationship between energy consumption and economic growth in Nigeria. In this study, he further disaggregated the energy consumption into oil, gas and electricity consumption in order to present a more robust analysis. The data from 1970-2005 were utilised to present a more tough analysis about relationship between energy consumption and economic growth. The finding from Toda-Yamamoto non-causality test revealed that there was unidirectional relationship from total energy consumption to economic growth. On the other hand, oil consumption and gas consumption were also found to have a unidirectional relationship on economic growth, without feedback causality. However, the electricity consumption had no causal relationship with economic growth. The empirical findings showed that an increased energy consumption would have beneficial effect on the economic growth. So, Nigeria needed to increase investment in its energy sector especially in infrastructure development on oil and gas.

Yuan et al. (2008) conducted a study on energy consumption and economic growth at both aggregate and disaggregate levels in China. Using Johansen cointegration and Granger causality, they found that a unidirectional causality ran from electricity consumption to economic growth, as well as from economic growth to total energy consumption and coal consumption. There was also bidirectional causality between oil consumption and economic growth in both the short and long run. They proposed that China needed to increase its energy efficiency to save energy and develop its renewable energy to enhance energy security.

In addition, Belloumi (2009) investigated the causal relationship between energy consumption and economic growth in Tunisia from 1971 to 2004. Belloumi (2009) also used Johansen cointegration and VECM Granger causality test in Tunisia. The findings showed the existence of a bidirectional causality between GDP and energy consumption in the long run, but a unidirectional causality running from energy consumption to GDP existed in the short run. From these findings, Belloumi (2009) suggested that Tunisia should rely more on renewable energy that can solve energy problems in Tunisia.

Gelo (2009) carried out a study to test the relationship between economic growth and energy consumption in Croatia. The data from 1953-2005 were utilised to present a stronger analysis about the relationship between energy consumption and economic growth. The finding from vector autoregression (VAR) model revealed that they were not significant in the model between variable total primary energy consumption and the constant, but variable GDP is significant in this model. Furthermore, the finding from Granger causality test indicated there was unidirectional causality relationship from total energy consumption to GDP without any feedback.

Besides that, Hou (2009) also carried out a study to test the causal relationship between energy consumption and economic growth in China. The data from 1953-2006 were utilised to present a more tough analysis about relationship between energy consumption and economic growth. The finding from Johansen cointegration showed there was no cointegration between energy consumption and economic growth. The finding from Hsiao's Granger causality test showed there was bidirectional causal relationship between economic growth and energy consumption. The main policy suggested by Hou (2009) was to enhance energy efficiency especially in the industrial and residential sectors.

Unlike the previous studies, Odhiambo (2009) conducted a study to examine the causal relationship between energy consumption and economic growth in Tanzania. The data used in this study was from 1971 until 2006. In this study, Odhiambo (2009) used two proxies of energy consumption, which are total energy consumption per capita and electricity consumption per capita. The methods used by Odhiambo (2009) in this study were ARDL bounds testing approach and Granger non-causality test. The finding from ARDL bounds testing approach showed that there was a stable long run relationship between each proxies of energy consumption and economic growth. Besides that, the finding from Granger non-causality test demonstrated that there was a unidirectional causal flow from total energy consumption to economic growth in the both short and long run. There was also a short run unidirectional causal flow from electricity consumption to economic growth. In general in this study, energy consumption urges economic growth in Tanzania.

Payne (2009) conducted a study on the dynamics of energy consumption and output in the US. In this study, Payne (2009) compared the causal relationship between renewable and real GDP, and non-renewable energy consumption and real GDP respectively. They used data from 1949 until 2006, in a multivariate modal framework which included capital and employment as additional variables. The methodology that Payne (2009) employed was Toda-Yamamoto which were the modified version of the Granger causality test. Payne (2009) found that the renewable energy consumption had no Granger causality with real GDP. In terms of non-renewable energy consumption, the author found that non-renewable energy consumption did not have Granger causality with real GDP. So, both of the renewable and non-renewable energy consumption are supportive of the neutrality hypothesis in this study.

A study done by Narayan and Wong (2009) on panel data analysis of the determinants of oil consumption was examined in Australia from 1985 until 2006. Narayan and Wong (2009) utilised Pedroni panel cointegration, fully modified ordinary least squares (FMOLS) panel long run estimators and panel Granger causality test in their study. The findings showed that there was unidirectional causality running from economic growth to oil consumption in the short run. Moreover, income had positive significant effect on oil consumption in the long run. As a conclusion, Narayan and Wong (2009) pointed out that the price of oil could not be increased because it would cause inflation in Australia.

Different from the previous studies, Bartleet and Gounder (2010) investigated the energy consumption and economic growth nexus using demand side and production models in New Zealand. The ARDL bound test and Granger causality test found a long run relationship existed between energy consumption and economic growth in both demand and production models. Moreover, the study also showed that a short run causality relationship existed from economic growth to energy consumption in both demand and production models too.

Additionally, Tsani (2010) investigated the causal relationship between energy consumption and economic growth in Greece from 1960 until 2006. Toda-Yamamoto Granger causality test suggested that total energy consumption had an impact on real GDP in the case of Greece. Tsani (2010) suggested that Greece needed to solve its energy import dependence and environmental issues without hindering economic growth.

In a more recent study by Stern and Enflo (2013), the authors examined the causality between energy and economic growth in Sweden. They applied Johansen cointegration and Toda-Yamamoto Granger causality test and found that energy had an impact on economic growth in the full sample (period from 1850 to 2000). But, different causality appeared when smaller samples test was taken, with causality running from economic growth to energy use from 1950 until 2000.

As a conclusion from the studies, they showed that different causality results were created from unidirectional causality, bidirectional causality and no causality. These conflicting results might be caused by different countries, time periods, methodologies that have been used by researchers. Table 2.3 shows the summary of literature reviews based on country-specific studies on relationship of energy consumption and economic growth.

Table 2.3: Summary of Empirical Studies on Country-Specific Studies on Energy Consumption and Economic Growth

Author(s) / Year	Period	Country	Methodology	Causality Relationship
Kraft and Kraft (1978)	1947-1974	US	Granger causality	GDP → EC
Cheng (1998)	1952-1995	Japan	Hsiao's Granger causality	GDP → EC
Stern (2000)	1948-1994	US	Granger causality	GDP ← EC
Aqeel and Butt (2001)	1955/56-1995/96	Pakistan	Hsiao's Granger causality	GDP → total EC GDP → Petroleum GDP --- Gas GDP ← Electricity
Soytas et al. (2001)	1960-1995	Turkey	Johansen cointegration, Granger causality, VECM	GDP ← EC (long & short run)
Chang et al. (2001)	1982:1-1997:11 (Monthly data)	Taiwan	Johansen cointegration, VECM, Granger causality, VDC, IRF	GDP ← EC
Paul and Bhattacharya (2004)	1950-1996	India	EG cointegration, Johansen cointegration, Granger causality	GDP → EC (long run) GDP ← EC (short run)
Lee and Chang (2005)	1954-2003	Taiwan	Johansen cointegration	GDP ↔ Total EC GDP ↔ Coal GDP ← Oil GDP ← Gas GDP ← Electricity

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, EG = Engle-Granger, VECM = vector error correction model, ECM = error correction model, VAR = vector autoregression, ARDL = autoregressive distributed lag, VDC = variance decomposition, IRF = impulse response functions, FMOLS = fully modified ordinary least squares.

Table 2.3: Summary of Empirical Studies on Country-specific Studies on Energy Consumption and Economic Growth (Continued)

Author(s) / Year	Period	Country	Methodology	Causality Relationship
Jobert and Karanfil (2007)	1960-2003	Turkey	Cointegration, Granger causality	GDP --- EC
Lise and Montfort (2007)	1970-2003	Turkey	Cointegration, Granger causality	GDP → EC
Zamani (2007)	1967-2003	Iran	Johansen cointegration, ECM	GDP → Total EC; GDP ↔ Gas & Petroleum (long run) GDP → Total EC & Petroleum
Erdal et al. (2008)	1970-2006	Turkey	Johansen cointegration, Pairwise Granger causality	GDP ↔ EC
Olusegun (2008)	1970-2005	Nigeria	ARDL, Toda-Yamamoto non-causality test	GDP ← Total EC, Oil & Gas GDP --- Electricity
Yuan et al. (2008)	1963-2005	China	Johansen cointegration, Granger causality, VECM	GDP ← Electricity GDP → Total EC, Coal GDP ↔ Oil (long & short run)
Belloumi (2009)	1971-2004	Tunisia	Johansen cointegration, Granger causality, VECM	GDP ↔ EC (long run) GDP ← EC (short run)
Gelo (2009)	1953-2005	Croatia	VAR, Pairwise Granger causality	GDP ← EC
Hou (2009)	1953-2006	China	Hsiao's Granger causality	GDP ↔ EC

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, EG = Engle-Granger, VECM = vector error correction model, ECM = error correction model, VAR = vector autoregression, ARDL = autoregressive distributed lag, VDC = variance decomposition, IRF = impulse response functions, FMOLS = fully modified ordinary least squares.

Table 2.3: Summary of Empirical Studies on Country-specific Studies on Energy Consumption and Economic Growth (Continued)

Author(s) / Year	Period	Country	Methodology	Causality Relationship
Odhiambo (2009)	1971-2006	Tanzania	ARDL, Granger non-causality	GDP ← Total EC (long & short run) GDP ← Electricity (short run)
Payne (2009)	1949-2006	US	Toda-Yamamoto causality test	GDP --- EC (non- & renewable energy)
Narayan and Wong (2009)	1985-2006	Autralia	Pedroni panel cointegration, FMOLS panel long run estimators	GDP → Oil (short run)
Bartleet and Gounder (2010)	1960-2004	New Zealand	ARDL, Granger causality	GDP → EC
Tsani (2010)	1960-2006	Greece	Toda-Yamamoto causality test	GDP ← EC
Stern and Enflo (2013)	1850-2000	Sweden	Johansen cointegration, Toda-Yamamoto causality test	GDP ← EC GDP → EC (1950-2000 subsample)

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, EG = Engle-Granger, VECM = vector error correction model, ECM = error correction model, VAR = vector autoregression, ARDL = autoregressive distributed lag, VDC = variance decomposition, IRF = impulse response functions, FMOLS = fully modified ordinary least squares.

2.4 Multi-country Studies on Energy Consumption and Economic Growth

Nowadays, there are voluminous literatures on both energy consumption and economic growth which examine both energy consumption and economic growth in various countries or a group of countries. For instance, there are Common Market of Eastern and Southern Africa (COMESA) countries (Nondo et al., 2010), Group of Seven (G7) (Soytas and Sari, 2003), Gulf Cooperation Council (GCC) countries (Al-Iriani, 2006), Organisation for Economic Co-operation and Development (OECD) countries (Belke et al., 2011). The previous empirical studies brought various findings by utilising different sample data and methodologies.

In previous studies for Malaysia in Section 2.2, Aziz (2011) ascertained that unidirectional causality existed from economic growth to energy consumption. Yet, Nanthakumar and Subramaniam (2010) as well as Islam et al. (2013) revealed that there was bidirectional relationship between energy consumption and economic growth. In other words, the findings of energy consumption and economic growth in Malaysia are not conclusive. The incompatible results for Malaysia also existed in the multi-country studies (see Masih and Masih, 1996a; Lee, 2005; Mahadevan and Asafu-Adjaye, 2007; Chiou-Wei et al., 2008; Lee and Chang, 2008; Apergis and Tang, 2013).

Masih and Masih (1996a) conducted a study on the causal relationship between energy consumption and economic growth in six Asian economies, namely Pakistan, Malaysia, Singapore, India, Indonesia and the Philippines. By using Johansen cointegration and VECM Granger causality test, they noted that there was no causality relationship between energy consumption and economic growth in

Malaysia, Singapore and the Philippines. However, there was unidirectional causality from energy consumption to economic growth in India, as well as from economic growth to energy consumption in Indonesia. Bidirectional causality between these two variables exists in Pakistan. By way of variance decomposition test, the result showed that income would lead energy consumption. In other words, income played leading role.

Again, Masih and Masih (1997) carried out a study to test the causal relationship between energy consumption, real income and prices in two highly energy dependent East-Asian countries, which are Korea and Taiwan. The data from 1955-1991 was utilised in this study for Korea and data from 1952-1992 was used for Taiwan. The finding from Johansen-Juselius's likelihood ratio and trace tests indicated that there existed at most two cointegrating vectors in Korea and only one cointegrating relationship in Taiwan. Next, the result of VECM and Granger (temporal) causality showed that energy affected income in the short run in Korea. In addition, they found that there was bidirectional causality between income and energy consumption in Taiwan. The variance decomposition showed that price shocks in Taiwan were much more influential in affecting both income and energy consumption in Korea.

Besides that, Glasure and Lee (1997) conducted a study about the relationship between GDP and energy in South Korea and Singapore. The data that they utilised was from 1961 until 1990 to examine the relationship between GDP and energy. The methodologies that Glasure and Lee (1997) used were the cointegration test, VECM and Granger causality test. In this research, they found that a unidirectional causal relationship ran from energy consumption to GDP in Singapore and no causality relationship exists between energy consumption and GDP in South Korea.

Conversely, Asafu-Adjaye (2000) was one of researchers who examined the relationship between energy consumption and economic growth in Asian countries by using ECM and Granger causality test. From 1971 until 1995, Asafu-Adjaye (2000) indicated that bidirectional causality existed between energy consumption and economic growth in the Philippines and Thailand. Nevertheless, unidirectional causality existed from energy consumption to economic growth in India and Indonesia from 1973 to 1995.

In addition, Soytas and Sari (2003) investigated the causal relationship between energy consumption and economic growth in the G7 countries, namely Argentina, France, Italy, Germany, Japan, Korea, and Turkey. They found that there was unidirectional causality running from economic growth to energy consumption in Italy and Korea. In the case of Argentina, they found that bidirectional causality existed between energy consumption and economic growth. Besides that, a unidirectional causality running from energy consumption to economic growth existed in France, Japan, Germany and Turkey.

A study on the causal relationship between energy consumption and GDP in several developing regions was examined by Lee (2005). The developing regions included East Asia, East Europe and Central Asia, Latin America, Southeast Asia, South Asia and Sub-Saharan Africa countries. Lee (2005) employed heterogeneous panel cointegration and panel-based ECM in this study. The finding showed that there was a unidirectional causality running from energy consumption to GDP. The finding proves that energy consumption led to economic growth in the panel of developing regions.

Other than that, Wolde-Rufael (2005) conducted a study about the relationship between energy use and economic growth in nineteen African countries. Wolde-Rufael (2005) used Toda-Yamamoto causality test, from 1971 until 2001. In the case of Algeria, Democratic Republic of the Congo, Egypt, Ghana and Ivory Coast, there was unidirectional causality running from GDP to energy use, exactly the reverse causality for Cameroon, Morocco and Nigeria. The study also showed that neutrality hypothesis or no causality existed between GDP and energy use among other African countries.

Al-Iriani (2006) implemented on study of the causality relationship between economic growth and energy consumption in six GCC countries. Al-Iriani employed the study from 1971 until 2002 and developed heterogeneous panel cointegration, panel generalised method of moments (GMM) and causality test in this study. The six GCC countries that were chosen by Al-Iriani (2006) were countries of relatively vast oil reserves which use cheap energy obtained from oil production. They were Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (UAE). The empirical result indicated that unidirectional causality existed from economic growth to energy consumption.

Lee (2006) investigated the causality relationship between energy consumption and economic growth in eleven countries, which were different countries from Lee's (2005). The Toda-Yamamoto Granger non-causality test was applied to investigate the causal relationship. The results showed that the existence of a bidirectional causality between energy consumption and economic growth in US only. Unidirectional causality running from energy consumption to economic growth existed in Belgium, Canada, the Netherlands and Switzerland, exactly the reverse causality for France, Italy and Japan. In the case of Germany, Sweden and the United Kingdom, there had no causality existed in this research.

Additionally, Mahadevan and Asafu-Adjaye (2007) studied energy consumption and economic growth with twenty net energy importers and exporters, from 1971 to 2002. Among the energy exporters, there was bidirectional relationship between GDP and energy consumption in both the short and long run which only existed in developed countries, while unidirectional causality existed from energy consumption to economic growth in the short run which existed in developing countries. Moreover, there was unidirectional causality running from energy consumption towards GDP in both the short and long run among energy importers. In the case of energy importers of developed countries, there also existed short run unidirectional causality running from GDP to energy consumption.

Nevertheless, Mehrara (2007) investigated a study on energy consumption and economic growth in eleven selected oil exporting countries in Middle East, Africa and Central and South America. He utilised data from 1971 until 2002. The findings from Pedroni panel cointegration test showed that there was unidirectional strong causality from economic growth to energy consumption in these eleven selected oil exporting countries. The empirical finding indicated that energy conservation policy should be implemented in these oil exporting countries.

Akinlo (2008) carried out a study to test the nexus between energy consumption and economic growth in eleven Sub-Sahara African countries. The data that was used in this study was from 1980 until 2003. The result from ARDL bounds test showed that the energy consumption cointegrated with economic growth in Cameroon, Cote D'Ivoire, Gambia, Ghana, Senegal, Sudan and Zimbabwe. It also suggested that energy consumption had a significant positive long run impact on economic growth in Ghana, Kenya, Senegal and Sudan. The results from Granger causality test based on VECM showed that there was bidirectional relationship between energy consumption and economic growth for Gambia, Ghana and Senegal. A unidirectional relationship also existed from economic growth to energy consumption in Congo, Sudan and Zimbabwe. Therefore, there was no causal relationship or neutrality hypothesis between energy consumption and economic growth for Cameroon, Cote D'Ivoire, Kenya, Nigeria and Togo.

Chiou-Wei et al. (2008) also investigated the relationship between energy consumption and economic growth in Asian countries and the United States. The findings from Chiou-Wei et al. (2008) indicated that there was unidirectional causality from economic growth to energy consumption in the Philippines and Singapore, exactly the reverse for Indonesia, Hong Kong, Malaysia and Taiwan. Therefore, there was neutrality hypothesis between energy consumption and economic growth for South Korea, Thailand and US.

Lee and Chang (2008) conducted a study on energy consumption and economic growth in Asian economies. Sixteen Asian countries selected by Lee and Chang (2008) included China, India, Indonesia, Japan, Malaysia, the Philippines, South Korea, Singapore and others. They developed heterogeneous panel cointegration, panel-based ECM in their study. They found that a long run unidirectional causality running from energy consumption to economic growth existed in these sixteen Asian countries. But, there was no any causality between economic growth and energy consumption in the short run.

The application of panel analysis in six Central America countries was being utilised in the studies by Apergis and Payne (2009a). The six Central America countries were Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama. They used data from 1980 until 2004 in this study. The finding from heterogeneous panel cointegration test shows the existence of long run equilibrium between real GDP and energy consumption. Then, the results from panel VECM and Granger causality indicates that both the short and long run causality existed from energy consumption to economic growth which supported the growth hypothesis.

Meanwhile, Apergis and Payne (2009b) once again examined the relationship between energy consumption and economic growth in eleven Commonwealth of Independent States. Based on heterogeneous panel cointegration test and panel ECM, unidirectional causality from energy consumption to economic growth existed in the short run, while bidirectional causality existed between energy consumption and economic growth in the long run, from 1991 until 2005.

Dipendra (2009) carried out a study to test the causal relationship between GDP per capita and energy consumption per capita by panel analysis for eighty eight countries. The eighty eight countries included fifty eight developing and thirty developed countries, which are Argentina, Brazil, Canada, China, France, Germany, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, Nigeria, Pakistan, the Philippines, Saudi Arabia, Singapore, South Africa, Thailand, Turkey, UAE, the United Kingdom (UK), US, and others. The data that Dipendra (2009) used was the annual data from 1975-2003 for all countries. The findings from panel cointegration test found that energy consumption per capita and GDP per capita were cointrgrated. Moreover, the findings from Granger causality model with a dynamic error term or dynamic panel VECM causality tests revealed that there was evidence of a short run, long run and strong two-way Granger causality between GDP growth rates (per capita) and energy consumption growth.

On top of that, Wolde-Rufael (2009) also studied seventeen African countries. By using Toda-Yamamoto causality test, the results showed that there was a unidirectional causality from economic growth to energy consumption in Egypt, Ivory Coast, Morocco, Nigeria, Senegal, Sudan, Tunisia and Zambia, and a reverse causality existed in Algeria, Benin and South Africa. Bidirectional causality between energy consumption and economic growth existed in Ghana, Gabon, Togo and Zimbabwe, while no causality was supported in Cameroon and Kenya.

Meanwhile, Apergis and Payne (2010) also did a study on the relationship between energy consumption and economic growth in nine South American countries over the period 1980 to 2005. As many previous studies used panel analysis, Apergis and Payne (2010) employed heterogeneous panel cointegration, panel ECM and panel Granger causality test in their research. Among nine South American countries, a unidirectional causality relationship existed from energy consumption to economic growth in the short and long run.

Nondo et al. (2010) also conducted a study to test the long run relationship between energy consumption and GDP in nineteen countries of COMESA with used panel analysis. The annual data from 1980-2005 were utilised to present a more stringent analysis on the relationship between energy consumption and economic growth. The finding from panel cointegration showed that there was a long run relationship between energy consumption and GDP. The panel Granger causality tests found that there was unidirectional Granger causality relationship from energy consumption to GDP in the short and long run.

Odhiambo (2010) examined the relationship between energy consumption and economic growth in three sub-Saharan African countries, namely South Africa, Kenya and Congo. The data from 1972-2006 were utilised to present more convincing analysis on the relationship between energy consumption and economic growth. The methods used in this study were ARDL bounds testing approach and Granger non-causality tests. The results of ARDL bounds testing approach found that causality existed between energy consumption and economic growth and varies significantly across South Africa, Kenya and Congo. The results from Granger non-causality tests showed that there a unidirectional causality relationship existed from energy consumption to economic growth in South Africa and Kenya, and unidirectional causality relationship existed from economic growth to energy consumption in Congo.

Ozturk et al. (2010) examined the relationship between energy consumption and economic growth in fifty one countries, which were divided into three groups-low income countries, middle income countries and upper middle income countries.

They used panel causality test and found that a unidirectional causality existed from economic growth to energy consumption in low income countries and bidirectional causality existed between two variables in lower middle and upper middle income countries.

In a similar study, Belke et al. (2011) carried out a study to examine the long run relationship between energy consumption and economic growth in twenty five OECD countries. The data from 1981-2007 were utilised to present a more stringent analysis on the relationship between energy consumption and real GDP, including energy prices. The findings from cointegration test between common components and panel-based error-correction (to test for Granger causality) showed that a long run relationship existed between energy consumption and real GDP. They also indicated that there was a bidirectional causality relationship between energy consumption and economic growth.

In a more recent study by Apergis and Tang (2013), they carried out a study to find out if energy leads to growth in eighty five selected countries, which included thirty four high income, eighteen upper middle income, twenty four lower middle income and nine low income countries. Using Toda-Yamamoto causality test, they found that only forty six out of eighty five countries showed strong support for the growth hypothesis. It meant a strong causality relationship ran from energy to economic growth in these forty six countries, which were Argentina, Austria, Belgium, Brazil, Brunei, Canada, Chile, Congo Republic, Colombia, Costa Rica, Cuba, Denmark, Dominican Republic, Ecuador, Finland, Greece, Guatemala, Honduras, Hong Kong, India, Indonesia, Iran, Italy, Jamaica, Japan, Jordan, Kenya, Korea, Malaysia, Mexico, Norway, Oman, Pakistan, Paraguay, Peru, Spain, Sudan, the Philippines, the UAE, UK, and US, Thailand, Tunisia, Turkey, Uruguay, and Venezuela.

Overall results from the previous studies showed conflicting results. As discussed before, varied results may be caused by diverse countries, time periods, methodologies that were used by the researchers. Table 2.4 shows the summary of literature reviews on multi-country studies on the relationship of energy consumption and economic growth.

Table 2.4: Summary of Empirical Studies on Multi-Specific Studies on Energy Consumption and Economic Growth

Author(s) / Year	Period	Country	Methodology	Causality Relationship
Masih and Masih (1996a)	1955-1990	6 Asian countries	Johansen cointegration, VECM, Granger causality	GDP ← EC (India) GDP ↔ EC (Pakistan) GDP → EC (Indonesia) GDP --- EC (Malaysia, Philippines, Singapore)
Masih and Masih (1997)	1955-1991 1952-1992	Korea Taiwan	Johansen cointegration, VECM, Granger causality	GDP ← EC (Korea) GDP ↔ EC (Taiwan)
Glasure and Lee (1997)	1961-1990	South Korea, Singapore	Granger causality	GDP --- EC (South Korea) GDP ← EC (Singapore)
Asafu-Adjaye (2000)	1971-1995 1973-1995	The Philippines, Thailand India, Indonesia	ECM, Granger causality	GDP ↔ EC (Philippines, Thailand) GDP ← EC (India, Indonesia)
Soytas and Sari (2003)	1950-1992	G7 countries	ECM, Granger causality	GDP ↔ EC (Argentina) GDP → EC (Italy, Korea) GDP ← EC (Turkey, France, Japan, Germany)
Lee (2005)	1975-2001	18 developing countries	Heterogeneous panel cointegration, panel ECM, FMOLS	GDP ← EC

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, VECM = vector error correction model, ECM = error correction model, ARDL = autoregressive distributed lag, FMOLS = fully modified ordinary least squares, GMM = generalized method of moments.

Table 2.4: Summary of Empirical Studies on Multi-specific Studies on Energy Consumption and Economic Growth (Continued)

Author(s) / Year	Period	Country	Methodology	Causality Relationship
Wolde-Rufael (2005)	1971-2001	19 African countries	Toda-Yamamoto causality test	GDP → EC (Algeria, Congo DR, Egypt, Ghana, Ivory Coast) GDP ← EC (Cameroon, Morocco, Nigeria) GDP ↔ EC (Gabon, Zambia) GDP --- EC (Benin, Congo RP, Kenya, Senegal, South Africa, Sudan, Togo, Tunisia, Zimbabwe)
Al-Iriani (2006)	1971-2002	6 GCC countries	Heterogeneous panel cointegration, GMM	GDP → EC
Lee (2006)	1960-2001 (1965-2001: Canada; 1971-2001: Germany)	Belgium, Canada, France, Italy, Japan, Germany, Netherlands, Sweden, Switzerland, UK, US	Toda-Yamamoto Granger non-causality test	GDP ← EC (Belgium, Canada, the Netherlands and Switzerland) GDP → EC (France, Italy, Japan) GDP ↔ EC (US) GDP --- EC (Germany, Sweden, UK)
Mehrara (2007)	1971-2002	11 oil exporting countries	Pedroni panel cointegration	GDP → EC

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, VECM = vector error correction model, ECM = error correction model, ARDL = autoregressive distributed lag, FMOLS = fully modified ordinary least squares, GMM = generalized method of moments.

Table 2.4: Summary of Empirical Studies on Multi-specific Studies on Energy Consumption and Economic Growth (Continued)

Author(s) / Year	Period	Country	Methodology	Causality Relationship
Mahadevan and Asafu-Adjaye (2007)	1971-2002	20 energy importers and exporters	Panel cointegration, panel VECM, GMM	*Energy Exporters:* GDP ↔ EC (developed countries, short & long run) GDP ← EC (developing countries, short run) *Energy Importers:* GDP ← EC (short & long run) GDP → EC (developed countries, short run)
Akinlo (2008)	1980-2003	11 Sub-Sahara African countries	ARDL bound test, VECM, Granger causality	GDP ↔ EC (Gambia, Ghana & Senegal) GDP → EC (Congo, Sudan & Zimbabwe) GDP --- EC (Cameroon, Cote D'Ivoire, Kenya, Nigeria and Togo)

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, VECM = vector error correction model, ECM = error correction model, ARDL = autoregressive distributed lag, FMOLS = fully modified ordinary least squares, GMM = generalized method of moments.

Table 2.4: Summary of Empirical Studies on Multi-specific Studies on Energy Consumption and Economic Growth (Continued)

Author(s) / Year	Period	Country	Methodology	Causality Relationship
Chiou-Wei et al. (2008)	1954-2006	Asian countries and US	Granger causality	GDP → EC (Philippines & Singapore) GDP ← EC (Indonesia, Hong Kong, Malaysia & Taiwan) GDP --- EC (South Korea, Thailand & US)
Lee and Chang (2008)	1971-2002	16 Asian countries	Heterogenous panel cointegration, panel ECM	GDP ← EC (long run) GDP --- EC (short run)
Apergis and Payne (2009a)	1980-2004	6 Central America countries	Heterogenous panel cointegration, panel VECM, panel Granger causality	GDP ← EC (short & long run)
Apergis and Payne (2009b)	1991-2005	11 Commonwealth of Independent States countries	Heterogenous panel cointegration, panel ECM	GDP ↔ EC (long run) GDP ← EC (short run)
Dipendra (2009)	1975-2003	88 countries	Panel cointegration, dynamic panel VECM causality	GDP ↔ EC (short & long run)

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, VECM = vector error correction model, ECM = error correction model, ARDL = autoregressive distributed lag, FMOLS = fully modified ordinary least squares, GMM = generalized method of moments.

Table 2.4: Summary of Empirical Studies on Multi-specific Studies on Energy Consumption and Economic Growth (Continued)

Author(s) / Year	Period	Country	Methodology	Causality Relationship
Wolde-Rufael (2009)	1971-2004	17 African countries	Toda-Yamamoto causality test	GDP → EC (Egypt, Ivory Coast, Morocco, Nigeria, Senegal, Sudan, Tunisia & Zambia) GDP ← EC (Algeria, Benin & South Africa) GDP ↔ EC (Ghana, Gabon, Togo & Zimbabwe) GDP --- EC (Cameroon & Kenya)
Apergis and Payne (2010)	1980-2005	9 South American countries	Heterogeneous panel cointegration, panel ECM, panel Granger causality	GDP ← EC (short & long run)
Nondo et al. (2010)	1980-2005	19 COMESA countries	Panel cointegration, panel Granger causality	GDP ← EC (short & long run)
Odhiambo (2010)	1972-2006	3 Sub-Saharan African countries	ARDL bound test, Granger non-causality	GDP ← EC (Kenya & South Africa) GDP → EC (Congo)
Ozturk et al. (2010)	1971-2005	51 countries	Pedroni panel cointegration, panel Granger causality	GDP → EC (low income countries) GDP ↔ EC (lower middle and upper middle income countries)

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, VECM = vector error correction model, ECM = error correction model, ARDL = autoregressive distributed lag, FMOLS = fully modified ordinary least squares, GMM = generalized method of moments.

Table 2.4: Summary of Empirical Studies on Multi-specific Studies on Energy Consumption and Economic Growth (Continued)

Author(s) / Year	Period	Country	Methodology	Causality Relationship
Belke et al. (2011)	1981-2007	25 OECD countries	Panel cointegration, panel ECM	GDP ↔ EC
Apergis and Tang (2013)	1975-2007	85 countries	Toda-Yamamoto causality test	GDP ← EC (only 46 countries)

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, VECM = vector error correction model, ECM = error correction model, ARDL = autoregressive distributed lag, FMOLS = fully modified ordinary least squares, GMM = generalized method of moments.

2.5 Studies on Energy Consumption, Economic Growth and CO_2 Emissions

Energy studies related to environmental issues have become popular as they relate to environmental science, climatology and so on. Thus, studies on carbon dioxide (CO_2) emissions are always included in studies of energy consumption and economic growth (see Ang, 2008; Chang, 2010; Lean and Smyth, 2010a; Pao and Tsai, 2010; Li et al., 2011; Niu et al., 2011; Alkhathlan et al., 2012; Alkhathlan and Javid, 2013).

For example, Ang (2008) has examined the relationship between output, pollutant emissions and energy consumption in Malaysia, using the annual data from 1971 to 1999. He adopted Johansen cointegration and VECM Granger causality test to analysis the relationship between output, CO_2 emissions and energy consumption. The main findings showed a unidirectional causality running from CO_2 emissions and energy consumption to output in the long run. Ang (2008) found a strong support causality running from output to energy consumption in the short and long run. A weak causality running from CO_2 emissions to output in the long run existed in this study. He suggested that policy makers should be aware about the environmental quality because a decline in environmental quality may exert a negative externality to the Malaysian economy.

Besides that, Chebbi (2009) conducted a study about the relationship between economic growth, energy consumption and CO_2 emissions in Tunisia. The data that Chebbi (2009) used were from 1971 until 2004. The findings from Johansen-Juselius cointegration test showed that there was a long run relationship in this modal. Moreover, there was a unidirectional causality running from CO_2 emissions growth to output growth or GDP by using the Granger causality test. There also was bidirectional causality running from output growth and energy consumption growth in the long run. This implied that Tunisia is an energy dependent economy. The generalised impulse response functions showed that the impact of an output growth is positive and significant for energy consumption and GDP, but insignificant for CO_2 emissions. The impact of a positive shock on CO_2 emissions is positive and significant for CO_2 emissions and energy consumption, but insignificant for GDP. The impact of a positive shock on energy consumption is positive but statistically insignificant for GDP, energy consumption and CO_2 emissions.

Zhang and Cheng (2009) investigated the temporal linkage between energy consumption, CO_2 emissions and economic growth in China. Zhang and Cheng (2009) used the data from 1960 until 2007. The findings from Granger causality test showed that there was a unidirectional Granger causality running from GDP to energy consumption in the long run. Moreover, the unidirectional Granger causality relationship from energy consumption to CO_2 also came about in this test. The study showed that neither CO_2 nor energy consumption will lead to economic growth. Another finding from generalised impulse response was that a shock in GDP has higher initial impacts on energy consumption than the other variables and the impacts lasted longer than CO_2 emissions. In this study, the results of generalised impulse response were supported by Granger causality tests.

Using the same country as Zhang and Cheng (2009), and Chang (2010) studied the correlations between CO_2 emissions, energy consumption and economic growth in China. She adopted annual data from 1981 to 2006 with disaggregate energy consumption (crude oil, natural gas, coal and electricity consumption), GDP and CO_2 emissions. The results from Granger causality found that a unidirectional causality ran from electricity and natural gas consumption to GDP. The results also found that a unidirectional causality ran from GDP to oil, coal consumption and CO_2 emissions. Besides, there was a unidirectional causality from all energy consumption towards CO_2 emissions. In this study, Chang (2010) proposed that the Chinese government should focus more on renewable energy programme to mitigate CO_2 emissions.

Unlike the previous studies, Lean and Smyth (2010a) used electricity consumption, CO_2 emissions and economic growth to investigate the causal relationship in five ASEAN countries. They employed panel VECM and panel Granger causality for Indonesia, Malaysia, the Philippines, Singapore and Thailand from 1980 until 2006. The long run relationship indicated that there was a unidirectional causality from electricity consumption and CO_2 emissions to GDP. The result of a short run causality existed from CO_2 emissions to electricity consumption in five ASEAN countries.

Using the same methodologies (panel Granger causality test), Pao and Tsai (2010) studied the relationship between CO_2 emissions, energy consumption and economic growth in Brazil, Russia, India and China (BRIC) from 1971-2005, except for Russia (1990-2005). In this study, they found that strong bidirectional causality existed between energy consumption and CO_2 emissions; and energy consumption and output in long run causality. The short run dynamics suggested a unidirectional causality from CO_2 emissions to GDP; and energy consumption to GDP without any feedback. There was also bidirectional causality between energy consumption and CO_2 emissions in the short run. Based on the findings, it was suggested that energy conservation policies should be implemented in BRIC countries to reduce unnecessary wastage of energy and increase energy efficiency.

Menyah and Wolde-Rufael (2010) conducted a study about the relationship between energy consumption, pollutant emissions (CO_2 emissions) and economic growth in South Africa, by using data from 1965 until 2006. Menyah and Wolde-Rufael (2010) found the existence of short and long run relationship among all the variables by using the ARDL bound test approach to cointegration test, with a positive and a significant relationship between pollutant emissions and economic growth. The result of Granger causality test found that there was a unidirectional relationship running from pollutant emissions to economic growth, from energy consumption to economic growth and from energy consumption to CO_2 emissions. The empirical findings suggested that there was a need to find alternative energies to reduce CO_2 emissions in South Africa.

In addition, Hatzigeorgiou et al. (2011) studied energy intensity rather than energy consumption in their study. Their results of examining the casual relationship between GDP, energy intensity and CO_2 emissions in Greece indicate that there is a long run unidirectional causality running from GDP to energy intensity. Also, there is a unidirectional causality running from GDP to CO_2 emissions in both long run and short run. On the other hand, there is bidirectional causality between energy intensity and CO_2 emissions in long run. A short run causal relationship running from energy intensity to CO_2 emissions is also detected in this study. Hatzigeorgiou et al. (2011) suggested that the development of a more efficient energy-economic system will resulted in a less harmful economic growth as well as a reduction in emissions in Greece.

At the same time, Li et al. (2011) studied energy consumption, economic growth and CO_2 emissions in China. They used data from 1985 to 2007, by method of panel unit root, heterogeneous panel cointegration and panel-based Dynamic Ordinary Least Squares (DOLS) in mainland China. The main findings showed that GDP had significant impact on CO_2 emissions. It was found that an increase of 1 per cent in GDP will increase energy consumption by 0.48 per cent to 0.50 per cent and accordingly increase CO_2 emissions to between 0.41 per cent and 0.43 per cent in the long term. On the other hand, Li et al. (2011) also found that there was a long run equilibrium relationship between economic growth and energy consumption in China. Through this study, they suggested that a low carbon economy be developed and to combine construction of resources saving societies and environmental friendly societies in China.

Moreover, Niu et al. (2011) also revealed that economic growth, energy consumption and CO_2 emissions had significant impact in eight Asia-Pacific countries, namely Australia, New Zealand, Japan and Korea as developed countries and China, Indonesia, Thailand and India as developing countries. They found different findings for these developed and developing countries. A long run relationship existed between CO_2 emissions and all variables (GDP, total energy consumption, coal, oil, natural gas and electricity) but there was no cointegration between natural gas, electricity and CO_2 emissions for developing countries. For developed countries, there was a unidirectional causality running from coal and natural gas to GDP, as well as from coal to CO_2 emissions in the short run. In the case of developing countries, there was a unidirectional causality running from total energy consumption to CO_2 emissions, as well as from CO_2 emissions to oil in the short run. In the long run, developing countries showed that there was unidirectional causality from CO_2 emissions to GDP. Although there were mixed results for developed and developing countries, Niu et al. (2011) suggested that these countries needed to carefully design their energy policies. These countries, especially for developing countries, should determine how to maintain economic growth while conserving energy and reducing CO_2 emissions.

Meanwhile, Alkhathlan et al. (2012) explored economic growth, CO_2 emissions, energy consumption and an additional variable, employment ratio, to observe the long and short run relationship in Saudi Arabia. They discovered CO_2 emissions, energy consumption and employment ratio had positive significant impact on GDP in the long run. In the short run, there was no causality relationship existed between economic growth, energy consumption and CO_2 emissions. But they found that long run income elasticity of CO_2 emissions is greater than the short run. In other words, it implied that GDP led to greater CO_2 emissions in Saudi Arabia. They suggested that Saudi Arabia needed to protect the environment without affecting the growth process of the country.

Similar to the study by Ang (2008), Ismail and Mawar (2012) studied energy use, CO_2 emissions, and economic growth with additional variables, capital and export to examine their relationships in Malaysia, using annual data from 1971 to

2007. Results of Granger non-causality showed that unidirectional short run causality ran from energy to GDP and capital, as well as from GDP to capital. In addition, there was also a unidirectional causality from CO_2 emissions to export in the short run. Therefore, Ismail and Mawar (2012) justified that there were long run feedback effects between energy and economic growth, and CO_2 emissions and economic growth. In their study, they suggested that the Malaysian government can increase energy use and improve its energy supply so that Malaysia does not suffer from lack of energy supplies.

Alkhathlan and Javid (2013) studied about the relationship between economic growth, CO_2 emissions and energy consumption at aggregate and disaggregate levels in Saudi Arabia. They employed ARDL cointegration approach and VECM Granger causality. They found that there was unidirectional causality running from aggregate energy consumption to GDP in the long run. However, bidirectional causality existed between CO_2 emissions and energy consumption in both the short and long run. In the case of oil consumption, there was unidirectional short run causality running from oil consumption to GDP, as well as from GDP to CO_2 emissions. In the case of gas consumption, there was unidirectional short run causality from GDP to gas consumption, as well as from CO_2 emissions to GDP. Alkhathlan and Javid (2013) suggested that the Saudi government could increase the energy price and this would decrease the energy consumption and decrease the CO_2 emissions also.

Additionally, Chandran and Tang (2013b) examined about the nexus of CO_2 emissions, economic growth and coal consumption in China and India. Their empirical results suggest that the variables are cointegrated in the case of China but not in the case of India. They found that there is a unidirectional relationship from GDP to CO_2 emissions in China. Besides that, bidirectional causality is also detected between GDP and coal consumption in China, CO_2 emissions and coal consumption in China and India, as well as GDP and CO_2 emissions in India.

Meanwhile for the case of India, Chandran and Tang (2013b) discover that there is a unidirectional causality running from GDP to coal consumption in short run. From these findings, it is suggested that China should be cautious in implementing any conservation policy while India should implement the policy without a destabilization of a long run economic growth.

Furthermore, Salahuddin and Gow (2014) examined the empirical relationship between economic growth, energy consumption and CO_2 emissions in all GCC countries. In this study, they unveil the existence of a unidirectional causality running from economic growth to energy consumption. Moreover, they also found out that there is bidirectional causality between energy consumption and CO_2 emissions. These findings recommend that pursuing favourable regulatory policies would promote various initiatives to reduce emissions.

Table 2.5 shows the summary of literature reviews on the relationships between energy consumption, economic growth and CO_2 emissions.

Table 2.5: Summary of Empirical Studies on Energy Consumption, Economic Growth and CO_2 Emissions

Author(s) / Year	Period	Country	Methodology	Main Finding
Ang (2008)	1971-1999	Malaysia	Johansen cointegration, VECM	CO2 & EC → GDP (long run) GDP → EC (short and long run)
Chebbi (2009)	1971-2004	Tunisia	Johansen cointegration, Granger causality, GIRF	GDP ↔ EC (long run) CO2 → GDP (short run)
Zhang and Cheng (2009)	1960-2007	China	Granger causality, GIRF	GDP → EC (long run) EC → CO2 (long run)
Chang (2010)	1981-2006	China	Johansen cointegration, Granger causality	Electricity & Gas → GDP GDP → CO2, Oil, Coal Oil, Gas, Coal, Electricity → CO2
Lean and Smyth (2010a)	1980-2006	5 ASEAN countries	Panel VECM, panel Granger causality	Electricity & CO2 → GDP (long run) CO2 → EC (short run)
Menyah and Rufael (2010)	1965-2006	South Africa	ARDL, Granger non-causality, VDC	CO2 → GDP GDP ← EC EC → CO2
Pao and Tsai (2010)	1971-2005 (Russia: 1990-2005)	BRIC countries	Panel Granger causality	EC ↔ CO2; EC ↔ GDP (long run) CO2 → GDP; EC → GDP; EC ↔ CO2 (short run)

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, CO2 = carbon dioxide emissions, ARDL = autoregressive distributed lag, VECM = vector error correction model, GIRF = generalized impulse response functions, DOLS = dynamic ordinary least squares, VDC = variance decomposition.

Table 2.5: Summary of Empirical Studies on Energy Consumption, Economic Growth and CO_2 Emissions (Continued)

Author(s) / Year	Period	Country	Methodology	Main Finding
Hatzigeorgiou et al. (2011)	1977-2007	Greece	Johansen cointegration, Granger causality	GDP → EI (long run) GDP → CO2 (short & long run) EI → CO2 (long run) EI → CO2 (short run)
Li et al. (2011)	1985-2007	China	Heterogeneous panel cointegration, Panel DOLS	Positive long run relationship between GDP and EC ↑1%GDP, ↑0.48-0.50% EC, ↑0.41-0.43% CO2
Niu et al. (2011)	1971-2005	8 Asia-Pacific countries (Developed and developing countries)	Panel cointegration, panel VECM Granger causality	*Developed countries:* Coal & gas → GDP; coal → CO2 (short run) *Developing countries:* Total EC → CO2; CO2 → oil (short run) CO2 → GDP (long run)
Alkhathlan et al. (2012)	1980-2008	Saudi Arabia	ARDL bound test, Granger causality	CO_2 emissions, energy consumption & employment ratio → GDP (long run) GDP --- EC & CO2 (short run)
Ismail and Mawar (2012)	1971-2007	Malaysia	Johansen cointegration, Granger non-causality	Energy → GDP & capital; GDP → capital; CO2 → export (short run)

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, CO2 = carbon dioxide emissions, EI – energy intensity, ARDL = autoregressive distributed lag, VECM = vector error correction model, GIRF = generalized impulse response functions, DOLS = dynamic ordinary least squares, VDC = variance decomposition.

Table 2.5: Summary of Empirical Studies on Energy Consumption, Economic Growth and CO_2 Emissions (Continued)

Author(s) / Year	Period	Country	Methodology	Main Finding
Alkhathlan and Javid (2013)	1980-2011	Saudi Arabia	ARDL cointegration approach, Granger causality, VECM	*Aggregate energy consumption:* EC → GDP (long run) CO2 ↔ EC (short & long run) CO2 ↔ GDP (short run) *Oil consumption:* GDP & oil → CO2 (long run) CO2 ↔ EC (short & long run) Oil → GDP; GDP → CO2 (short run) *Gas consumption:* EC → GDP (long run) CO2 ↔ EC (short & long run) GDP → gas; CO2 → GDP (short run) *Electricity consumption:* EC → GDP (long run) CO2 ↔ EC (short & long run)

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, CO2 = carbon dioxide emissions, ARDL = autoregressive distributed lag, VECM = vector error correction model, GIRF = generalized impulse response functions, DOLS = dynamic ordinary least squares, VDC = variance decomposition.

Table 2.5: Summary of Empirical Studies on Energy Consumption, Economic Growth and CO_2 Emissions (Continued)

Author(s) / Year	Period	Country	Methodology	Main Finding
Chandran and Tang (2013b)	1965-2009	China and India	Bayer and Hanck cointegration, Granger causality test	*China:* GDP → CO2 (short & long run) GDP ↔ coal (short & long run) CO2 ↔ coal (short & long run) *India:* GDP ↔ CO2 (short run) CO2 ↔ coal (short) GDP → coal (short)
Salahuddin and Gow (2014)	1980-2012	GCC countries	Panel cointegration, panel Granger causality	EC ↔ CO2 GDP → EC

Notes: → and ← indicates unidirectional causality. ↔ indicates bidirectional causality. --- indicates no causality. Abbreviations are defined as follows: GDP = gross domestic product, EC = energy consumption, CO2 = carbon dioxide emissions, ARDL = autoregressive distributed lag, VECM = vector error correction model, GIRF = generalized impulse response functions, DOLS = dynamic ordinary least squares, VDC = variance decomposition.

2.6 Concluding Remarks

To sum up, the energy literature reviewed in this chapter has provided useful information on the variables used in energy supply and consumption studies. GDP is one of the common variables that are included in investigating a macroeconomic energy model. The previous studies have suggested that income can be measured by the GDP level.

Meanwhile, most of previous studies have also included pollution emissions variable into the energy model. Following the common practice in previous studies, most researchers used CO_2 emissions as the proxy for the level of pollution. Inclusion of CO_2 emissions variable in the energy model is important especially in those countries that still relied on fossil fuels. This is because the findings of these studies will provide clear and distinct energy policies aim to reduce emissions.

From the literature reviewed, a gap still exists in the energy studies conducted in sub-energy or disaggregated energy study. Not only that such gap existed in terms of the amount of studies conducted but as well in the depth level of disaggregated energy studies. For example, Lean and Smyth (2014a) have studied disaggregated energy demand in Malaysia, which is a very specific and new area of energy study. Other than that, disaggregated energy supply has been rarely investigated in energy studies. At the same time, in the case of energy supply, most of the previous studies only focused on electricity supply or electricity generation (see Yoo and Kim, 2006; Ghosh, 2009; Lean and Smyth, 2010b). Such studies, however, has not been conducted yet in sub-energy supply.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

Chapter Three is organised as below. Section 3.1 gives a description of the data concerned while Section 3.2 provides an explanation of variables that were employed to analyse the relationship between gross domestic product (GDP) and energy. The remaining section provides the empirical testing procedures in this research.

In general, this research adopted an empirical model and the econometrics methodology to achieve its objectives. The Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests were used to determine the order of integration for the variables. Then, the Johansen-Juselius cointegration test was employed to investigate the long run relationships among the variables. Next, the Granger causality test was applied to test and find out the causality direction. Finally, the Variance Decomposition (VDC) test was employed to gauge the strength of the causal relationship among the variables beyond the sample.

3.1 Data Description

Annual data from 1978 to 2010 for Malaysia's energy supply and from 1980 to 2010 for Malaysia's energy consumption was used in this study. The variables involved in this study are energy supply (ES), energy consumption (EC) as well as GDP and CO_2 emission for ES and EC in Malaysia. The data used in this study were retrieved from various issues of Malaysia Energy Information Hub (MEIH) provided by Energy Commissions for ES data, Asia-Pacific Economic Cooperation (APEC) energy database for EC and carbon dioxide (CO_2) emission by energy data and GDP data obtained from Department of Statistics Malaysia. All variables are transformed into natural logarithm form prior to estimation.

3.2 Empirical Model

The empirical model in this study is modified from the original traditional energy function (Kraft and Kraft, 1978) as follows:

$$Y = f\,(E) \qquad (1)$$

where Y represents GDP and E is energy. A number of studies have employed such model of two variables such as Masih and Masih (1996a), Morimoto and Hope (2004), Lee and Chang, (2005), Yoo and Kim (2006), Chontanawat et al. (2008), Belloumi (2009), Narayan et al. (2010), Nanthakumar and Subramaniam (2010), Narayan and Popp (2012), and Shaari et al. (2013).

Meanwhile, introducing a pollution variable (CO_2 emission) into the model as a control variable can be specified as follows:

$$Y = f\,(E, CO2) \tag{2}$$

where Y represents GDP, E is energy and $CO2$ is CO_2 emission by energy data. According to Ang (2008) as well as Lean and Smyth (2010a), they stated that CO_2 emission can be used as the proxy for the level of pollution since pollution emissions are primarily generated by burning fossil fuels. Energy in this study represents energy supply and energy consumption. For energy supply, five separate models for disaggregated energy by fuel type, in which replace E replaced with each of the five fuel types in turn.

These five disaggregated energy supply by fuel types included crude oil, petroleum products, natural gas, coal and coke and hydropower. Similarly, energy consumption was divided into four separate models, which includes oil and petroleum products, natural gas, coal and coke as well as electricity consumption.

Apart from the study done by Ang (2008) that has included CO_2 emission in the model, Stern (2000), Aqeel and Butt (2001), Apergis and Payne (2009c), Soytas and Sari (2009), Zhang and Cheng (2009), Chang (2010), Lean and Smyth (2010a), Menyah and Wolde-Rufael (2010), Bari et al. (2012), Saboori and Sulaiman (2013), Chandran and Tang (2013a) have also extended the multivariate setting to include CO_2 emissions.

In the past decade, only a few energy studies conducted are related to energy supply and economic growth, such as Morimoto and Hope (2004) for the case of Sri

Lanka, Yoo and Kim (2006) for the case of Indonesia, Ghosh (2009) for the case of India, respectively. These empirical studies have mixed findings and were inconclusive in their findings on the causality relationship between GDP and energy supply. On that note, this study will analyse the relationship between economic growth and energy supply in Malaysia.

Theoretically, economic development of an economy is closely related to energy condition in which energy is described by Stern (2000) as well as Noor and Siddiqi (2010) as the main factor behind economic growth. Higher economic growth is expected when more energy is consumed or used. Unquestionably, an increase in energy demand will see an increase in energy supply as well. This is the basic demand-supply function proposed in many economic textbooks.

Moreover, as the previous chapter has pointed out voluminous articles had examined the causal relationship between energy consumption and economic growth after Kraft and Kraft (1978). Alternatively, this study will analyse the relationship between economic growth, energy consumption and CO_2 emissions in Malaysia. As Malaysia consumed more than 97 per cent of fossil fuels, this might lead to environmental issues, of which highlight the inclusion of CO_2 emissions by energy in the energy consumption model for this study.

In addition, energy supply is defined as an energy that has not undergone the transformations or conversion process. In this study, energy supply will separate into two models, with and without CO_2 emission. The advantage of employed bivariate model in energy supply is to observe the direct causality relationship between these two variables. Trivariate model by accommodating CO_2 emissions into the model also take part in energy supply to obtain additional information for causality relationship.

3.3 Empirical Testing Procedures

3.3.1 Unit Root Tests

The empirical testing procedures start off with examining the time series properties of each variable under study by utilizing the unit root test. In other words, the purpose of unit root test is to determine whether the time series is consistent with *I(1)* process with a stochastic trend or if it is consistent with *I(0)* process in which means that it is stationary with a deterministic trend. Chebbi and Boujelbene (2008) stated that the unit root test will have little power when the number of observation is low (short-spanned data). Similar statement was documented as well by Costantini and Martini (2010). Thus, in order to overcome this problem as well as to ensure the robustness of the estimation, two types of unit root test are used to examine the time series properties of the variables under study. Two types of unit root tests that will be conducted in this study are Augmented Dickey-Fuller (ADF) test[5] which test the null hypothesis of unit root and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test which test the null hypothesis of stationarity. This procedure follows Chebbi and Boujelbene (2008) in which they applied these two different unit root tests in their study.

ADF (1979) unit root test is applied in this study to test the variables for their time properties. ADF unit root test is employed to examine the existence of unit root

[5] Discussion in this section (ADF test) is adapted from Dritsaki, Dritsaki and Adamapoulos (2004, pp.231-232).

in the data series for each variable, in order to answer whether the variables are either stationary in level *I(0)* or first differences *I(1)* (Fuller, 1976; Dickey and Fuller, 1979). The optimal lag lengths for ADF unit root test are based on the automatic selection procedure of Schwarz Information Criterion (SIC). The ADF unit root test regression can be expressed as follow:

$$X_t = \alpha_0 + \alpha_1 t + \alpha_2 X_{t-1} + \sum_{i=1}^{k} \beta_i \Delta X_{t-1} + \mu_t \tag{3}$$

where Δ denotes the first difference, X_t is all model variables at time *t* in logarithm, *k* is the lag length, ΔX_{t-1} is the first difference with *k* lags and also μ_t is the variable that adjusts the errors of autocorrelation. Besides that, α_0, α_1, α_2, and β_i are the parameters to be estimated. The null and alternative hypotheses of the ADF unit root test of a variable X_t is defined as:

$$H_0 : \alpha_2 = 0 \tag{4}$$

$$H_1 : \alpha_2 < 0 \tag{5}$$

The null hypothesis for the unit roots test in level and first difference is "unit root exist" meanwhile the alternative hypothesis is "unit root does not exist". If the null hypothesis of a unit root in the time series cannot be rejected at a 5 per cent level of significance in variable level where α_2 equal to zero, it reveals that unit root occurs for the variable in level form. However, if α_1 is significantly negative varies from zero, the null hypothesis of the ADF can be rejected. Thus, first difference has to be proceeded if it performs stationary.

Besides that, in order to get robust results of the time properties of the variables, KPSS test is also applied in this paper. The null hypothesis of KPSS test is contrasted with the ADF test where the variable is stationary.

$$KPSS = \frac{1}{T^2}\sum_{t=11}^{T} S_2 \big/ \sigma_\infty^2 \tag{6}$$

where $S_t = \sum_{j=1}^{t} w_j$ with $w_t = y_t - \bar{y}$ and σ_∞^2 is an estimator of

$$\sigma_\infty^2 = \lim_{T \to \infty} T^{-1} Var\left(\sum_{t=1}^{T} Z_t\right) \tag{7}$$

That is, σ_∞^2 is an estimator of the long run variance of the process z_t .If y_t is a stationary process, S_t is $I(1)$ and the quantity in the numerator of the KPSS statistic is an estimator of its variance, which has a stochastic limit. The term in the denominator ensures that, overall; the limiting distribution is free of unknown nuisance parameters. If, however, y_t is, the numerator grows without bounds, causing the statistic to become large sample sizes.

Kwiatkowski, Phillips, Schmidt and Shin (1992) in order to avoid strong assumptions regarding the process z_t, proposed a nonparametric estimator of σ_∞^2 based on a Barlett window having, once again, a lag truncation parameter $l_q = q(T/100)^{1/4}$:

where $w_j = 1 - \frac{j}{i_{q+1}}$, as before. Using this estimator, the KPSS statistic is found to have a limiting distribution that does not depend on nuisance parameters under the null hypothesis of stationary of y_t. Hence, critical values can be tabulated provided z_t satisfies the same weak conditions. The critical values may be found, for example, in Kwiatkowski, Phillips, Schmidt and Shin. (1992).

At first, the variables are estimated in level form with trend and intercept[6]. This result would be reported if the trend value is significant (less than 5 per cent of significance level) and if the trend is not significant, then the result of estimation with specific intercept would be reported. Then, in the first difference form, the trend value would be eliminated and the variables would only be estimated with intercept. The estimation would continue until stationary of the variable had been obtained.

3.3.2 Johansen-Juselius Cointegration Test

Johansen-Juselius cointegration test introduced by Johansen and Juselius (1990) is the common test used to test the long run relationship between variables, which in this research are economic growth and energy. The Johansen cointegration test is performed on vector autoregression (VAR) of various lag length in order to determine the appropriate lag length.

The Johansen procedure employs two likelihood ratio (LR) test statistics to determine the number of cointegrating vectors namely; the trace test and the maximal eigenvalue (λmax) test. The trace test evaluates the null hypothesis that there is *r* or fewer cointegrating vectors against a general alternative. For the

[6] Elder & Kennedy (2001) argued that it is important to determine if an intercept or an intercept with a time trend is to be used in the unit root test. They added that the unit root test will be biased or in low power when there are too many deterministic regressors and inclusion of intercept or intercept with time trend is necessary to allow representation of the alternative hypothesis competing against the null hypothesis of the unit root test.

maximum eigenvalue test, the alternative hypothesis is clear. The null hypothesis r = 0 is tested against the alternative where r = 1, r = 1 against r = 2, and so on.

Trace test statistic is computed as follows:

$$T_{trace} = -T \sum_{i=r+1}^{p} In\,(1 - \lambda_1) \tag{8}$$

Where λ_1 is the $p-r$ small square canonical correlation of V_{01} with respect to V_{1t}. The null hypothesis of trace test is of r or less cointegrating vectors where: $r = 0,1,2,\ldots p-1, p$. In another equation expression is $r \le 1, r \le 2 \ldots r \le p$. The maximum eigenvalue test statistic is estimated by the following equation:

$$\lambda_{max} = -T\,\mathrm{In}(1 - \lambda_{r-t}) \tag{9}$$

In maximum eigenvalue test, the r versus $r+1$ is examined. Thus, the null hypothesis of $r = 0$ is examined against the alternate hypothesis of $r = 0,1,2,\ldots p-1, p$.

3.3.3 Granger Causality Test

Misspecification problems can be avoided if Granger causality test is conducted in vector error correction model (VECM), if the cointegration is detected (Granger, 1988). Equation (1) and Equation (2) are then estimated by using the VECM, which incorporates with the error correction term (ECT) from the cointegrating equation to capture long-term deviation from the equilibrium relationship between GDP-ES and GDP-EC. According to Granger representation theorem, if the variables are non-stationary and cointegrated, then we may proceed to estimate the vector error-correction mechanism model. On the other hand, if the variables are non-stationary and not cointegrated, we have to follow the standard VAR in estimation. The residuals from the cointegration equation can be used as an error-correction representation since there is existence of a cointegrated relationship in the long run as follows:

$$\Delta GDP_t = \alpha + \sum_{i=1}^{p} \beta_i \, \Delta GDP_{t-i} + \sum_{i=1}^{p} \emptyset_i \, \Delta ES_{t-i} + \mu ECT_{t-1} + \theta_t \qquad (10)$$

$$\Delta ES_t = \varphi + \sum_{i=1}^{p} \delta_i \, \Delta ES_{t-i} + \sum_{i=1}^{p} \gamma_i \, \Delta GDP_{t-i} + \lambda ECT_{t-1} + \sigma_t \qquad (11)$$

where ΔGDP_t is gross domestic product and ΔES_t is energy supply. θ_t, and σ_t are white noise and p refers to the order of lag for ΔGDP_t, and ΔES_t. The μ and λ are coefficient in the ECT. However, the existence of a cointegrated relationship in the long run for the energy supply with CO_2 emissions is expressed as follows:

$$\Delta GDP_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta GDP_{t-i} + \sum_{i=1}^{p} \emptyset_i \Delta ES_{t-i} + \sum_{i=1}^{p} \eta_i \Delta CO_{2t-i} + \mu ECT_{t-1} + \theta_t \qquad (12)$$

$$\Delta ES_t = \varphi + \sum_{i=1}^{p} \delta_i \Delta ES_{t-i} + \sum_{i=1}^{p} \Upsilon_i \Delta GDP_{t-i} + \sum_{i=1}^{p} \omega_i \Delta CO_{2t-i} + \lambda ECT_{t-1} + \sigma_t \qquad (13)$$

$$\Delta CO_{2t} = \gamma + \sum_{i=1}^{p} \zeta_i \Delta CO_{2t-i} + \sum_{i=1}^{p} \pi_i \Delta GDP_{t-i} + \sum_{i=1}^{p} \nu_i \Delta ES_{t-i} + \psi ECT_{t-1} + \kappa_t \qquad (14)$$

where ΔGDP_t is gross domestic product, ΔES_t is energy supply and ΔCO_{2t} is CO_2 emission by energy. θ_t, σ_t and κ_t are white noise and p refers to the order of lag for ΔGDP_t, ΔES_t and CO_{2t}. The μ, λ and ψ are coefficients in the ECT.

Moreover, the residuals from the cointegration equation can be used as an error-correction representation since there is existence of a cointegrated relationship in the long run for the energy consumption as follows:

$$\Delta GDP_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta GDP_{t-i} + \sum_{i=1}^{p} \phi_i \Delta EC_{t-i} + \sum_{i=1}^{p} \eta_i \Delta CO_{2t-i} + \mu ECT_{t-1} + \theta_t \quad (15)$$

$$\Delta EC_t = \varphi + \sum_{i=1}^{p} \delta_i \Delta EC_{t-i} + \sum_{i=1}^{p} \gamma_i \Delta GDP_{t-i} + \sum_{i=1}^{p} \omega_i \Delta CO_{2t-i} + \lambda ECT_{t-1} + \sigma_t \quad (16)$$

$$\Delta CO_{2t} = \gamma + \sum_{i=1}^{p} \zeta_i \Delta CO_{2t-i} + \sum_{i=1}^{p} \pi_i \Delta GDP_{t-i} + \sum_{i=1}^{p} \nu_i \Delta EC_{t-i} + \psi ECT_{t-1} + \kappa_t \quad (17)$$

where ΔGDP_t is gross domestic product, ΔEC_t is energy consumption and ΔCO_{2t} is CO_2 emission by energy. θ_t, σ_t and κ_t are white noise and p refers to the order of lag for ΔGDP_t, ΔEC_t and ΔCO_{2t}. The μ, λ and ψ are coefficients in the ECT, measuring a single period response to a departure from equilibrium of the dependent variable. Take for example, to test whether EC does not Granger cause movement in GDP, H_0: $\phi_i = 0$ for all i and $\mu = 0$ in Equation (15). The rejection implies that EC causes GDP. Similarly, to test that GDP does not Granger cause movement in EC the null hypothesis, H_0: $\gamma_i = 0$ for all i and $\lambda = 0$ in Equation (16), where the rejection implies that GDP Granger cause EC.

There are two channels for detecting causality in a VECM framework. The first one is through the *F*-tests applied to the joint significance of the sum of the lags of each explanatory variable in the system. *F*-tests show the “short run” causal effects in their first differences for the explanatory variable. Secondly, it can be detected through the statistical significance of the *t*-test for the lagged ECT which indicates the "long run" causal relationship of the model. In the Granger causality test, the value of *F*-statistic is greater than the critical value, it will become statistically significant and can be rejected the null hypothesis, which is have Granger causal relationship. As a result, it will have a causality relationship between the variables. Furthermore, VECM indicates the econometric exogeneity of the variables if both the *F*-statistics relate to the explanatory variables and *t*-statistic relates to ECT and are insignificant (Puah and Jayaraman, 2007).

3.3.4 Variance Decomposition (VDC)

The inference from the application of Granger causality provide rich and dynamic framework in which causality may be tested but is strictly within the sample causality test (see Masih and Masih, 1996b). In order to gauge the relative strength of the variables while providing the dynamic properties of the system beyond the sample, the innovation (or shock) of the system is warranted using the forecast error variance decomposition[7]. VDC which may be termed as out-of-sample causality tests, partitioning the variance of the forecast error of a certain variable into proportions attributable to innovations (or shocks) in each variable in the system including its own, can provide an indication of these relativities. In this dynamic analysis, it would also be able to gauge the information on how much a variable affect the other variables even beyond the sample.

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[7] Cholesky decomposition would employ in this study although this approach is sensitive to the order in which the variables enter the model. In what follows, the innovations were orthogonalised in the following order: [GDP, Energy, CO_2]. The variance decomposition analysis reveals information on the proportion of the movements for instance in energy due to its "own" shocks versus shocks to the GDP. Similar analogy was applied to the other variables in responses to the exogenous shocks. Using the VDCs analysis, we are able to map out the dynamic response path of these variables, mimicking the forecasting process in time series modelling.

Basically, the dynamic tests strengthen the findings from causality analysis and provide further evidence of the empirical investigation. The dynamic analysis provides further forecasting ability which is able to foretell the responses of each given variable due to the movements in any other variable. In other words, VDC is able to further detect the relative strength of Granger causal chain and partition the variance of forecast error variance of each variable in the model based on Cholesky's decomposition (Masih and Masih, 1996b; Baharumshah and Lau, 2007).

The innovation of the VDC will be represented in percentage form and the strength of each variable to their own shocks and others are measured by the value to 100 per cent conducted using different horizons. In this study, VDC shows 48 years' time horizon.

CHAPTER FOUR

EMPIRICAL RESULTS AND DISCUSSIONS

4.0 Introduction

This study is set up to investigate the relationship between economic growth and disaggregate energies, which are energy supply and energy consumption in Malaysia. The five fuel types of energy supply which had been considered in this study are crude oil, petroleum products, natural gas, coal and coke, and hydropower. Meanwhile, four energy consumption by fuel types studied are oil and petroleum products, natural gas, coal and coke and electricity. The time period of this study covered from 1978 until 2010 for Malaysia's energy supply and covered from 1980 until 2010 for Malaysia's energy consumption.

This chapter presents the empirical results of the estimated model discussed in the earlier chapter (Chapter Three). In conducting empirical analysis, the first step is to apply the unit root tests to determine the order of integration among the variables. In this study, Augmented Dickey-Fuller (ADF) by Dickey and Fuller (1979) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (1992) are applied. After determining the order of integration of the variables, the next step is to conduct the Johansen and Juselius (1990) cointegration test to examine the existence of a long run relationship between the variables of study. Next, Granger causality test (Granger, 1988) is performed to test the Granger causal relationship among these variables. Lastly, Variance Decomposition (VDC) test is employ to gauge the strength of the causal relationship among the variables beyond the sample. The results are separated into three subsections of energy supply, energy supply with pollution variable and energy consumption.

4.1 Energy Supply

4.1.1 Unit Root Tests Results for Energy Supply

The first part of the analysis concentrates on investigating the nature of the data which involves testing the order of integration for each variable under study. The results of the unit root tests will determine the time series properties of the variables under study whether the variables are stationary in level or first difference form. In other words, the unit root tests determine whether the variables constructed in this study are *I(0)* or *I(1)*.

Table 4.1 shows the ADF unit root test and KPSS stationary tests results for each fuel type of energy supply and gross domestic product (GDP) in Malaysia. Six variables were included in this estimation, namely gross domestic product (GDP), crude oil (OIL), petroleum products (PET), natural gas (GAS), coal and coke (COAL), and hydropower (HYD).

Referring to the row for GDP variable, it can be observed that the t-statistic at level form is -2.3033. This value is smaller than the critical value of -3.5578 in magnitude at 5 per cent significant level. This result proves that GDP in level form fails to reject the null hypothesis because t-statistics value is smaller than the critical values. Therefore, the estimation proceeds to determine whether the time series property of GDP in first difference form. The result shows that the null hypothesis of intercept is rejected because t-statistics for intercept (-5.3813) exceeded the critical value (-2.9604) in magnitude, indicating that GDP is stationary in the first difference. Moreover, the results for other variable also show that the null hypothesis of non-stationary is not able to be rejected in the level form. However, the null hypothesis of non-stationary for other variables can be rejected at first difference form, viewing that all t-statistics are greater than the critical value at 5 per cent level of significance. All in all, all the variables integrated of order one or *I(1)*. In other words, ADF unit root test shows that all the variables are stationary in their first difference form.

Meanwhile, for the KPSS stationary test, the null hypothesis stated that the variable is stationary while the alternative hypothesis stated that the variable is not stationary. The null hypothesis for KPSS stationary test is rejected when the t-statistics value is bigger than the critical value in magnitude. For example, from Table 4.1, it can be observe that the t-statistic of OIL at level form of intercept is 0.1807. The value is greater than the critical value of 0.1460 in magnitude at 5 per cent significant level. This proves that OIL in level form does not satisfy the null hypothesis because t-statistics value is greater than the critical value. Therefore, KPSS stationary test proves that OIL is non-stationary at level form. On the other hand, for the case of OIL in first difference form, the t-statistics is smaller than the critical value in magnitude. Specifically, the t-statistics for first difference form of intercept (0.1994) is smaller than the critical value (0.4630). As such, it does not reject the null hypothesis in first difference form. This means that OIL is stationary at *I(1)*. For the remaining variables, the results are similar where they are non-stationary in level form but are stationary in their first difference form, implying that the six variables, namely GDP, OIL, PET, GAS, COAL and HYD are integrated at order one or *I(1)* such as proven by both ADF unit root test and KPSS stationary tests.

According to Nelson and Plosser (1982), they argued that most of the macroeconomic variables are non-stationary in level form and all data should have the same order of integration. Based on the empirical findings in this study, only the KPSS results for GDP is stationary in level form, but ADF results for GDP is non-stationary in level form. However, after first differencing, all the variables are stationary. Since all the variables are stationary at first difference or integrated at order one (*I(1)*), the next step is to proceed to the cointegration test.

Table 4.1: Unit Root Tests Results for Energy Supply

	ADF		KPSS	
	Intercept	**Trend and Intercept**	**Intercept**	**Trend and Intercept**
		Level		
GDP	-	-2.3033[0]	-	0.0809[3]
OIL	-	-1.1150[0]	-	0.1807[1]**
PET	-2.4830[1]	-	0.4851[3]**	-
GAS	-	-2.8189[0]	-	0.1837[1]**
COAL	-	-2.9327[0]	-	0.1522[4]**
HYD	-	-2.4573[2]	-	0.1601[4]**
		First Differences		
ΔGDP	-5.3813[0]**	-	0.1128[3]	-
ΔOIL	-3.8909[0]**	-	0.1994[5]	-
ΔPET	-7.7601[0]**	-	0.0936[3]	-
ΔGAS	-3.1126[6]**	-	0.0720[2]	-
ΔCOAL	-6.6408[0]**	-	0.2840[6]	-
ΔHYD	-4.9759[0]**	-	0.2807[3]	-

Notes: "Δ" is the first different operator. Asterisks (**) indicate statistical significance at 5 per cent level. Figures in […] are the lag lengths. The asymptotic and finite sample critical value for ADF is obtained from MacKinnon (1996). The ADF test examines the null hypothesis of a unit root against the stationary alternative. The KPSS test critical values are obtained from Kwiatkowski et al. (1992, Table 1, p.166). KPSS tests the null hypothesis that the series is stationary against the alternative hypothesis of a unit root.

4.1.2 Johansen-Juselius Cointegration Test Results for Energy Supply

Since all the variables are integrated of order one, the Johansen and Juselius (1990) cointegration test which examines the existence of a long run relationship among the variables of study was applied. Before applying Johansen-Juselius cointegration test, the optimum lag order (*k*) for the vector autoregression (VAR) to be applied in each cointegration test need to be determined first. The lag order is determined using the information provided by Schwarz Information Criterion (SIC). According to Tweneboah and Adam (2008), SIC is inclined to underestimation. While there is increased cost for loss of degree of freedom on the addition of more lags, SIC which typically chooses shorter lags is preferred. Thus, this study followed SIC which typically chooses shorter lags compared to Akaike information criterion. The results of the Johansen cointegration procedure are presented in Table 4.2.

Table 4.2 depicts both results of trace test and maximum eigenvalue (λ_{max}) for each energy supply of fuel type. For trace statistics, the null hypothesis $r = 0$ for energy supply by oil and coal are rejected at 5 per cent significant level since the value of trace statistics exceeded the 5 per cent critical values. Besides that, the null hypothesis of $r = 0$ for energy supply of petroleum, gas and hydropower are not rejected at 5 per cent significant level, in which the value of trace statistics are smaller than the 5 per cent critical values. Moving to the null hypothesis of $r \leq 1$, all the estimation of null hypothesis is not rejected at 5 per cent critical value.

As shown by the λ_{max} statistic results in Table 4.2, the null hypothesis of $r = 0$ for energy supply of oil is rejected at 5 per cent significant level as the λ_{max} value is larger than the critical value. Moreover, the null hypothesis of $r = 0$ for other energy supply fuel types are not rejected at 5 per cent significant level. Nevertheless, the null hypothesis of $r \leq 1$ is not rejected at 5 per cent level of significance for all energy supply of fuel types.

The results suggest that there is one cointegrating vector between economic growth and energy supply by oil and coal in Malaysia. Although for energy supply by coal, there is an existence of one cointegrating vector following the results of trace statistic, but there is no cointegrating vector according to the results of λ_{max} test statistic. According to Cheung and Lai (1993), trace test provides more robust results than λ_{max} of the same procedure, therefore, in the case of energy supply by coal, it is accepted that there is one cointegrating vector in this study. Hence, a long run stable linear equilibrium relationship is said to exist among the variables for energy supply by oil and coal. In other words, the variables are intimately bound in the long run for these two fuel types. The results showed that there are no long run relationship between economic growth and energy supply by petroleum, gas and hydropower.

Table 4.2: Johansen-Juselius Cointegration Test Results for Energy Supply

		λmax		Trace	
Null	**Alternative**	**Unadjusted**	**95% C.V**	**Unadjusted**	**95% C.V**
			Energy Supply by Oil		
			k = 1 r = 1		
r = 0	r = 1	17.0897**	15.8921	21.4230**	20.2618
r ≤ 1	r = 2	4.3333	9.1646	4.3333	9.1646
			Energy Supply by Petroleum		
			k = 1 r = 0		
r = 0	r = 1	11.7113	14.2646	11.9959	15.4947
r ≤ 1	r = 2	0.2845	3.8415	0.2845	3.8415
			Energy Supply by Gas		
			k = 1 r = 0		
r = 0	r = 1	8.8024	14.2646	9.1295	15.4947
r ≤ 1	r = 2	0.3271	3.8415	0.3271	3.8415
			Energy Supply by Coal		
			k = 1 r = 1		
r = 0	r = 1	15.6619	15.8921	24.4701**	20.2618
r ≤ 1	r = 2	8.8082	9.1645	8.8082	9.1645
			Energy Supply by Hydropower		
			k = 1 r = 0		
r = 0	r = 1	9.4638	14.2646	9.9894	15.4947
r ≤ 1	r = 2	0.5256	3.8415	0.5256	3.8415

Notes: k is the lag length and r is the cointegrating vector and r is number of cointegrating vectors that are significant under both tests. Asterisks (**) denote significance at 5 per cent level.

4.1.3 Normalizing the Cointegrating Vector for Energy Supply

Since a long term equilibrium relationship is found in the cointegration test, the next step is to normalize the obtained cointegration vector with respect to the dependent variable (GDP) to acquire the long term estimates for the independent variables. There is only one significant vector detected and do not have the problem of identification of the equation that represents the GDP. Table 4.3 reports the long run parameters of the model. The results show that there is a positive relationship between energy supply (oil and coal supply) and GDP. The estimated coefficient of oil supply is 0.93 and coal supply is 0.30. Such finding suggests that 1 per cent increase in oil supply (coal supply) will result in 0.93 (0.30) per cent increase in GDP. This result is consistent with finding of previous studies by Ang (2008), Yusoff and Latif (2013), Islam et al. (2013) and Mugableh (2013) that a positively relationship between energy consumption/demand and GDP in Malaysia.

Table 4.3: Normalizing the Cointegrating Vector for Energy Supply

Variables	GDP	Energy Supply
Energy Supply by Oil	1.0000	0.9295 (1.9217)
Energy Supply by Coal	1.0000	0.2966 (0.3607)

Note: The estimated coefficient was obtained by normalizing the GDP variable. The number in (…) denotes the t-statistics.

4.1.4 Granger Causality and Diagnostic Tests Based on VECM for Energy Supply

The cointegration test indicates that the two variables (GDP and oil supply; GDP and coal supply) are bound together by one long run equilibrium relationship but it does not reveal information about the direction of causal relationship between these variables. Table 4.4 reports the results of Granger causality test based on vector error correction model (VECM) which contains the error correction term (ECT) to measure the long run disequilibrium. Given the presence of a unique and single cointegrating vector following the cointegation test, we settle with one ECT for both oil and coal.

The results for VECM are portrayed in Table 4.4. First, it shows that no short run causality exists between GDP and energy supply by oil and coal. This result matches with the study by Shaari et al. (2013) which showed that oil and coal consumption does not have Granger causality with economic growth. While the previous study focused on consumption, the relationship between energy consumption and energy supply in this study can be related. This is because increase in energy consumption/demand will see an increase in energy supply. This is the basic demand-supply function proposed in many economic textbooks.

Second, the ECT is significant and the burden of short run adjustment is bear by GDP for energy supply by oil and coal, where the ECT carries the correct sign (negative). The speed of adjustment stands at 1.03 per cent per year in the case of energy supply by oil and 2.08 per cent per year in the case of energy supply by coal. So, these findings imply that Malaysia will need more than 97 years for oil and 48 years for coal to adjust back to equilibrium whenever disequilibrium happens. So, GDP functions as the initial receptor of any exogenous shocks that distort the equilibrium system in Malaysia. Furthermore, the ECT results show that there is an existence of a long run causality running from energy supply by oil and coal to GDP.

Table 4.4: Granger Causality Test Based on VECM for Energy Supply

Energy Supply	**Dependent Variables**	**χ^2-statistic (p-value)**		**ECT**	
		ΔGDP	ΔOIL	Coefficient	T-Statistic
Oil	ΔGDP	-	0.1545(0.6943)	-0.0103**	-4.2233
	ΔOIL	1.9179(0.1661)	-	-0.0001	-0.0111
		ΔGDP	ΔCOAL	Coefficient	T-Statistic
Coal	ΔGDP	-	0.0112(0.9158)	-0.0208**	-4.1964
	ΔCOAL	0.5424(0.4615)	-	-0.0439	-1.6956

Notes: "Δ" is the first different operator. Asterisks (**) indicate statistical significance at 5 per cent level.

To ascertain the appropriateness of the VECM model and to serve as robustness check purposes, the diagnostic and the stability tests are conducted and reported in Table 4.5. First, the Lagrange Multiplier (LM) test for residual serial correction finds no evidence of serial correction at lag one. The residuals are also multivariate normal. But, null hypothesis of normality is rejected for Jarque-Bera test for both oil and coal supply model. Besides that, the null hypothesis of no heteroskedasticity of residuals are also failed to be rejected for both oil and coal supply. The diagnostic tests results indicate that energy supply by oil and coal passed the tests of serial correlation and heteroskedasticity. In other words, oil and coal supply do not suffer from autocorrelation problem, and the obtained parameters are normally distributed with constant variance.

Table 4.5: Diagnostic Tests for VECM Results for Energy Supply

Tests	**Energy Supply by Oil**	**Energy Supply by Coal**
Serial Correlation	7.6053 [0.1072]	1.3734 [0.8488]
Normality – Jarque-Bera	11.8974 [0.0181]	25.1432 [0.0000]
Heteroskedasticity (No Cross Terms)	20.6439 [0.2978]	26.9286 [0.0803]
Heteroskedasticity (With Cross Terms)	33.9457 [0.1676]	48.2835 [0.0071]

Notes: Diagnostic tests: Serial Correlation = Lagrange Multiplier (LM) test of VEC residual serial correlation; Normality = Based on Cholesky of covariance (Lutkepohl) of VEC residuals; and Heteroskedasticity = Heteroskedasticity test of VEC residual. The figures in […] refer to the probabilities.

4.1.5 Granger Causality and Diagnostic Tests Based on first difference VAR for Energy Supply

For the remaining energy supply domain, Granger causality in VAR of first difference environment is conducted. As indicated in Table 4.6, the results clearly show that the short run unidirectional causality relationship from GDP to energy supply by petroleum and gas exist, in which the p-value is less than 5 per cent significant level. The findings conform to the previous study of Yoo and Kim (2006) and Ghosh (2009) where there is evidence of insignificant causality relationship between GDP and hydropower domain.

Table 4.6: Granger Causality Test in VAR of First Difference Results for Energy Supply

Energy Supply	Dependent Variables	χ^2-statistic (p-value)	
		ΔGDP	ΔPET
Petroleum	ΔGDP	-	0.9299(0.3349)
	ΔPET	5.2355**(0.0221)	-
		ΔGDP	ΔGAS
Gas	ΔGDP	-	0.6565(0.4178)
	ΔGAS	4.4030**(0.0359)	-
		ΔGDP	ΔHYD
Hydropower	ΔGDP	-	0.3313(0.5649)
	ΔHYD	1.1927(0.2748)	-

Notes: "Δ" is the first different operator. Asterisks (**) indicate statistical significance at 5 per cent level.

Furthermore, in order to check for model specification, Table 4.7 shows three diagnostic tests are imposed. First, the LM test for residual serial correlation finds no evidence of serial correlation. The residuals are also multivariate normal. Null hypothesis of normality is failed to be rejected for Jarque-Bera test (except petroleum supply). Besides that, the heteroskedasticity of residuals are also failed to be rejected for both with and without cross terms. Hence, the VAR model passes all the diagnostic tests without reservation.

Table 4.7: Diagnostic Tests for VAR of First Difference Results for Energy Supply

Tests	Energy Supply by Petroleum	Energy Supply by Gas	Energy Supply by Hydropower
Serial Correlation	1.9904 [0.7375]	8.2445 [0.0830]	0.9818 [0.9125]
Normality – Jarque-Bera	18.9873 [0.0008]	8.5151 [0.0744]	8.2785 [0.0819]
Heteroskedasticity (No Cross Terms)	20.987 [0.0506]	13.372 [0.3426]	14.0011 [0.3006]
Heteroskedasticity (With Cross Terms)	22.638 [0.0921]	14.9619 [0.4542]	19.2971 [0.2006]

Notes: Diagnostic tests: Serial Correlation = Lagrange Multiplier (LM) test of VAR residual serial correlation; Normality = Based on Cholesky of covariance (Lutkepohl) of VAR residuals; and Heteroskedasticity = Heteroskedasticity test of VAR residual. The figures in […] refer to the probabilities.

4.1.6 Variance Decomposition Test Results for Energy Supply

In order to gauge the relative strength of the variables and the transmission mechanism responses, we shock the system and partition the forecast error variance decomposition for each of the variables in the system (Masih and Masih, 1996b). The innovation of the VDC will be represented in percentage form and the strength of the two variables to their own shocks and each other are measured by the value up to 100 per cent. For the purpose of the analysis, the VDC is executed using time horizons of 1 to 48 years. We rely on the VDC to gauge the strength of the causal relationship between GDP and energy supply by fuel types and the results are given in Table 4.8. The major findings are discussed as follows.

Energy supply seems to be the most interactive variable in the system except for energy supply by coal. For example in the case of oil, the VDC shows that about 28 per cent of the forecast error variance can be explained by GDP at the end of the 48 year horizon. This provides evidence of strong direct causality originating from GDP to oil supply. Not only for energy supply by oil, VDC also shows that energy supply by gas has strong direct causality originating from GDP to gas supply. On the contrary, in the case of coal, the result shows that almost 40 per cent of the forecast error variance can be explained by energy supply by coal at the end of the 48 year horizon. This means there is a direct causality originating from energy supply by coal to GDP on the entire forecast horizon.

Belsley et al. (2004) stated the practical rule of thumb in their study that when a variable impact is below the threshold of 15 per cent or 30 per cent, the impact is suggested to be too weak for further consideration; regardless of what patterns of variance decomposition proportions may be associated with statistical hypothesis. In this study, we choose 15 per cent as a cut off line. Therefore, for the cases of petroleum and hydropower supply models, the variables do not have significant causality throughout the forecast horizon.

Besides that, the results of the VDC analysis in Table 4.8 reveal that supply of coal and oil are relatively more important than other energy supply (petroleum, gas and hydropower). Specially, approximately 53.8 per cent of the variation in economic growth can be explained by both coal (39.4 per cent) and oil (14.4 per cent). However, the supply of gas, petroleum and hydropower only justify about 18.7 per cent of the variation in Malaysia's economic growth at the end of the 48 year horizon. While VDC is not in line with causality interplay, it does give a view beyond the sample period, an important indication for policy impetus. According to BP Statistical Review (2014a), although coal consumption growth is slowing, it still remains as the largest source of power at global level and is expected to carry on to 2035. Such situation will directly or indirectly influence the global economic growth in the future.

Table 4.8: Variance Decomposition Test Results for Energy Supply

Percentage of variations in	Horizon	Due to innovation in: ΔGDP	ΔOIL
A. Energy Supply by Oil			
Years Relative Variance in: ΔGDP	1	**100.00**	0.00
	4	**99.13**	0.87
	8	**98.35**	1.65
	12	**97.49**	2.51
	24	**94.21**	5.79
	48	**85.58**	14.42
Years Relative Variance in: ΔOIL	1	13.56	**86.44**
	4	28.32	**71.68**
	8	30.05	**69.95**
	12	30.31	**69.69**
	24	29.86	**70.14**
	48	28.29	**71.71**
		ΔGDP	**ΔPET**
B. Energy Supply by Petroleum			
Years Relative Variance in: ΔGDP	1	**100.00**	0.00
	4	**97.03**	2.97
	8	**96.26**	3.74
	12	**96.01**	3.99
	24	**95.75**	4.25
	48	**95.63**	4.37
Years Relative Variance in: ΔPET	1	2.04	**97.96**
	4	2.26	**97.74**
	8	2.81	**97.19**
	12	3.29	**96.71**
	24	4.46	**95.54**
	48	5.90	**94.10**

Note: The column in bold represents their own shock.

Table 4.8: Variance Decomposition Test Results for Energy Supply (Continued)

Percentage of variations in	Horizon	Due to innovation in: ΔGDP	ΔGAS
C. Energy Supply by Gas			
Years Relative Variance in: ΔGDP	1	**100.00**	0.00
	4	**97.48**	2.52
	8	**94.41**	5.59
	12	**92.75**	7.25
	24	**90.87**	9.13
	48	**89.95**	10.05
Years Relative Variance in: ΔGAS	1	0.85	**99.15**
	4	9.35	**90.65**
	8	23.28	**76.72**
	12	33.56	**66.44**
	24	49.34	**50.66**
	48	59.87	**40.13**
		ΔGDP	**ΔCOAL**
D. Energy Supply by Coal			
Years Relative Variance in: ΔGDP	1	**100.00**	0.00
	4	**99.85**	0.15
	8	**99.02**	0.98
	12	**97.44**	2.56
	24	**88.52**	11.48
	48	**60.56**	39.44
Years Relative Variance in: ΔCOAL	1	3.82	**96.18**
	4	7.79	**92.21**
	8	7.55	**92.45**
	12	6.87	**93.13**
	24	4.86	**95.14**
	48	2.41	**97.59**

Note: The column in bold represents their own shock.

Table 4.8: Variance Decomposition Test Results for Energy Supply (Continued)

Percentage of variations in	Horizon	Due to innovation in: ΔGDP	ΔHYD
E. Energy Supply by Hydropower			
Years Relative Variance in: ΔGDP	1	**100.00**	0.00
	4	**99.15**	0.85
	8	**97.93**	2.07
	12	**97.16**	2.84
	24	**96.21**	3.79
	48	**95.72**	4.28
Years Relative Variance in: ΔHYD	1	0.02	**99.98**
	4	0.19	**99.81**
	8	1.00	**99.00**
	12	2.08	**97.92**
	24	5.14	**94.86**
	48	9.32	**90.68**

Note: The column in bold represents their own shock.

4.2 Energy Supply with Pollution Variable (Carbon Dioxide Emissions)

4.2.1 Unit Root Tests Results for Energy Supply with CO_2 Variable

The empirical testing procedure starts with the application of unit root tests which examine the order of integration for the variables under study. Table 4.9 shows the ADF unit root test and KPSS stationary test results for all fuel type of energy supply, GDP and CO_2 emissions in Malaysia. Seven variables were included in this estimation, namely gross domestic product (GDP), crude oil (OIL), petroleum products (PET), natural gas (GAS), coal and coke (COAL), hydropower (HYD) and carbon dioxide (CO2) emissions.

The results of ADF unit root test reveal that all the variables are non-stationary at the level form and on the other hand, the null hypothesis of non-stationary at first difference form is rejected viewing that all test statistics are greater than the critical value at 5 per cent level of significance. In view of this, the ADF unit root test results indicate that the selected variables in this study are stationary in first difference or *I(1)* processes.

In order to check for robustness of the ADF unit root test results, the KPSS stationary test is carried out to determine the stationarity properties of variables. This test has the null hypothesis of stationary against the alternative hypothesis of unit root. As shown in Table 4.9, KPSS results show that in level form, the hypothesis of stationary is rejected for all the variables under study, except for the GDP. Thus, the variables are said to be non-stationary and need to be differenced to achieve stationarity. In the first difference form, KPSS results fail to reject the null hypothesis of stationary for all the variables at 5 per cent significant level, indicating that the variables are integrated with the order of one. Although GDP is stationary in *I(0)*, this variable is also stationary at *I(1)*. At the same time, all the variables under study are stationary at *I(1*).

In nutshell, ADF unit root test as well as KPSS stationarity test clearly indicated that the specified variables are integrated in *I*(1) processes, and thus, this provides a good rationale for using the cointegration approaches as proposed by Johansen and Juselius (1990).

Table 4.9: Unit Root Tests Results for Energy Supply with CO_2 Variable

	ADF		**KPSS**	
	Intercept	**Trend and Intercept**	**Intercept**	**Trend and Intercept**
		Level		
GDP	-	-2.1316[0]	-	0.0891[3]
OIL	-	-0.8166[0]	-	0.1538[2]**
PET	-2.4157[1]	-	0.5271[3]**	-
GAS	-	-2.6962[0]	-	0.1899[1]**
COAL	-	-3.2817[0]	-	0.1813[1]**
HYD	-	-3.2253[1]	-	0.1507[2]**
CO2	-	-1.7651[0]	-	0.1932[1]**
		First Differences		
ΔGDP	-5.1206[0]**	-	0.0905[3]	-
ΔOIL	-3.8511[0]**	-	0.2344[5]	-
ΔPET	-7.5575[0]**	-	0.0998[3]	-
ΔGAS	-6.7439[0]**	-	0.0826 [1]	-
ΔCOAL	-6.9978[0]**	-	0.1632[1]	-
ΔHYD	-4.2732[3]**	-	0.1342[1]	-
ΔCO2	-4.5870[1]**	-	0.2244[7]	-

Notes: "Δ" is the first different operator. Asterisks (**) indicate statistical significance at 5 per cent level. Figures in […] are the lag lengths. The asymptotic and finite sample critical value for ADF is obtained from MacKinnon (1996). The ADF test examines the null hypothesis of a unit root against the stationary alternative. The KPSS test critical values are obtained from Kwiatkowski et al. (1992, Table 1, p.166). KPSS tests the null hypothesis that the series is stationary against the alternative hypothesis of a unit root.

4.2.2 Johansen-Juselius Cointegration Test Results for Energy Supply with CO_2 Variable

When the variables are integrated of same order, the empirical testing procedure proceed on to Johansen and Juselius (1990) cointegration test which will test on the existence of long run relationship among the variables of study. First of all, in estimating Johansen-Juselius cointegration test, the optimal lag order (*k*) should be selected for specification of model. Thus, we determined the lag order using the information provided by SIC.

As illustrated in Table 4.10, the results of Johansen and Juselius (1990) cointegration test report that both trace test and maximum eigenvalue (λ_{max}) are consistent. However, Cheung and Lai (1993) pointed out that trace test provide more robust results than maximum eigenvalue of the same procedures. Based on the trace test results, null hypothesis of $r = 0$ can be rejected at 5 per cent level of significance for oil, gas and coal supply, which the estimation is continued for the null hypothesis of $r \leq 1$. Referring to Table 4.10, the null hypothesis of $r \leq 1$ is not rejected at 5 per cent level of significance for oil, gas and coal supply. Other energy supply domains (petroleum and hydropower supply) failed to reject the null hypothesis of $r = 0$ in both trace test and λ_{max} test. These results indicate that there is a long run stable linear equilibrium relationship among the oil, gas and coal supply models. In other words, GDP, energy supply (oil, gas and coal) and CO_2 emissions are intimately bound in the long run.

Table 4.10: Johansen-Juselius Cointegration Test Results for Energy Supply with CO_2 Variable

Null	Alternative	λmax Unadjusted	λmax 95% C.V	Trace Unadjusted	Trace 95% C.V
			Energy Supply by Oil		
			k = 1 r = 1		
r = 0	r = 1	19.9527**	17.7973	27.8846**	24.2760
r ≤ 1	r = 2	7.1982	11.2248	7.9318	12.3209
r ≤ 2	r = 3	0.7336	4.1299	0.7336	4.1299
			Energy Supply by Petroleum		
			k = 1 r = 0		
r = 0	r = 1	11.5938	21.1316	19.6192	29.7971
r ≤ 1	r = 2	7.4041	14.2646	8.0254	15.4947
r ≤ 2	r = 3	0.6212	3.8415	0.6212	3.8415
			Energy Supply by Gas		
			k = 1 r = 1		
r = 0	r = 1	16.5763	21.1316	30.5343**	29.7971
r ≤ 1	r = 2	12.5157	14.2646	13.9580	15.4947
r ≤ 2	r = 3	1.4423	3.8415	1.4423	3.8415
			Energy Supply by Coal		
			k = 1 r = 1		
r = 0	r = 1	17.7475	17.7973	26.9000**	24.2760
r ≤ 1	r = 2	9.1518	11.2248	9.1521	12.3209
r ≤ 2	r = 3	0.0003	4.1299	0.0003	4.1299
			Energy Supply by Hydropower		
			k = 1 r = 0		
r = 0	r = 1	15.2292	21.1316	25.0753	29.7971
r ≤ 1	r = 2	8.3778	14.2646	9.8462	15.4947
r ≤ 2	r = 3	1.4684	3.8415	1.4684	3.8415

Notes: k is the lag length and r is the cointegrating vector and r is number of cointegrating vectors that are significant under both tests. Asterisks (**) denote significance at 5 per cent level.

4.2.3 Normalizing the Cointegrating Vector for Energy Supply with CO_2 Variable

In order to obtain the long run parameters of the model, we normalize the obtained cointegrating vector with respect to the dependent variable (GDP). There is only one significant vector detected and hence, do not have the problem of identification of the equation that represents the GDP. Table 4.11 reports the long run parameters of the model. The result shows a positive relationship between CO_2 emissions and GDP. The estimated coefficient of CO_2 emissions is 2.98 for oil supply model; 45.28 for gas supply model; and 1.19 for coal supply model, respectively. With regard to such findings, 1 per cent increase in CO_2 emissions will result in 1.19 to 45.28 per cent increase in GDP. These results are parallel with previous studies by Ang (2008), Azlina and Mustapha (2012), and Begum et al. (2015) which discovered that CO_2 emissions was positively associated with GDP in long run for Malaysia.

Unlike the results from bivariate model, the results show that energy supply by oil and gas negatively affects GDP in Malaysia. Although the direction of causality supports growth hypothesis where energy plays an important role in economic growth, but its negative coefficient sign produce a contradicting indication against the energy as an input of economic growth (Ismail and Mawar, 2012). This finding provides the possibility that including CO_2 emission as a control variable does not fit well for this model. Other possibilities to improve this model are to include more explanatory variables or using other measurement that is more representative of pollution variable.

Table 4.11: Normalizing the Cointegrating Vector for Energy Supply with CO_2 Variable

Variables	GDP	Energy Supply	CO2
Energy Supply by Oil	1.0000	-1.7304 (-1.2262)	2.9766 (1.1725)
Energy Supply by Gas	1.0000	-35.1543 (-8.3278)	45.2751 (11.2159)
Energy Supply by Coal	1.0000	0.0908 (0.0375)	1.1859 (0.0284)

Note: The estimated coefficient was obtained by normalizing the GDP variable. The number in (…) denotes the t-statistics.

4.2.4 Granger Causality and Diagnostic Tests Based on VECM for Energy Supply with CO_2 Variable

The cointegration test indicates that the three variables are bound together by one long run equilibrium relationship but it does not reveal any information with regard to the direction of causal relationship between these variables. Table 4.12 reports the results of Granger causality test based on VECM which contains the ECT that measures the long run disequilibrium. In order to evaluate the significance of lagged ECT, t-statistics are employed whereas the joint-significance of the lagged differenced variables is evaluated by employing the F-statistics. Moreover, the significant and correct sign (negative sign) of ECT reveals that a long run causal relationship exists between the specified variables in gas supply including the CO_2 emissions model.

As shown in Table 4.12, the estimated ECT coefficient for GDP has a correct negative sign and is statistically significant at the 5 per cent level. In the other word, ECT is significant and the burden of short run adjustment is bear by GDP for energy supply by oil and coal. The estimated ECT coefficient is -0.0949 for oil supply and -0.3261 for coal supply. The estimated coefficient of ECT indicates that almost 10 per cent for oil supply and 33 per cent for coal supply of the short run deviations would be adjusted each year towards the long run equilibrium level. The period to attain the equilibrium level for energy supply by oil and coal are less than ten years.

According to Masih et al. (2009), VECM plays an important role in detecting the endogeneity or exogeneity of the variables in the model. In the case of oil and coal supply, GDP functions as the initial receptor of any exogenous shocks that distort the equilibrium system in Malaysia. Furthermore, the ECT result shows that there is a long run causality running from oil and coal supply and CO_2 emission to GDP.

Besides that, the ECT is significant and the burden of short run adjustment is bear by gas supply for energy supply by gas model, where the ECT carries the correct negative sign. The speed of adjustment stands at 1.16 per cent per year, implying that Malaysia will need more than 86 years to adjust back to equilibrium whenever disequilibrium happens. Thus, energy supply by gas functions as the initial receptor of any exogenous shocks that distort the equilibrium system in Malaysia. Furthermore, the ECT result shows that there is an existence of a long run causality running from GDP and CO_2 emission to gas supply. Moreover, short run causal relationship does not exists between GDP, energy supply (oil, gas and coal) and CO_2 emission in Malaysia.

Table 4.12: Granger Causality Test Based on VECM for Energy Supply with CO_2 Variable

Energy Supply	**Dependent Variables**	**χ^2-statistic (p-value)**			**ECT**	
		ΔGDP	ΔOIL	ΔCO2	Coefficient	T-Statistic
Oil	ΔGDP	-	1.0816(0.2983)	0.5648(0.4523)	-0.0949**	-4.5891
	ΔOIL	2.0709(0.1501)	-	0.0196(0.8885)	-0.0080	-0.2686
	ΔCO2	0.5942(0.4408)	0.1697(0.6804)	-	-0.0413	-1.6789
		ΔGDP	ΔGAS	ΔCO2	Coefficient	T-Statistic
Gas	ΔGDP	-	0.0045(0.9467)	0.0001(0.9987)	0.0006	0.3121
	ΔGAS	3.7836 (0.0518)	-	0.4400(0.5071)	-0.0116**	-3.5879
	ΔCO2	0.3755(0.5400)	3.2647(0.0708)	-	0.0027	1.2993
		ΔGDP	ΔCOAL	ΔCO2	Coefficient	T-Statistic
Coal	ΔGDP	-	0.0319(0.8582)	1.2588(0.2619)	-0.3261**	-4.2091
	ΔCOAL	0.9986(0.3177)	-	0.0153(0.9016)	-0.2379	-0.5725
	ΔCO2	1.8621(0.1724)	0.5716(0.4496)	-	-0.1184	-1.3205

Notes: "Δ" is the first different operator. Asterisks (**) indicate statistical significance at 5 per cent level.

Subsequently, to ascertain the appropriateness of the VECM model and to serve as a robustness check purpose, the diagnostic and the stability tests are conducted and reported in Table 4.13. The diagnostic tests results indicate that all of the models passed the tests of serial correlation, normality and heteroskedasticity. In other words, all the models do not suffer from autocorrelation problem, and the obtained parameters are normally distributed with constant variance.

Table 4.13: Diagnostic Tests for VECM Results for Energy Supply with CO_2 Variable

Tests	Energy Supply by Oil	Energy Supply by Gas	Energy Supply by Coal
Serial Correlation	8.8578 [0.4505]	5.8029 [0.7595]	13.4305 [0.1441]
Normality – Jarque-Bera	9.9353 [0.1274]	11.2404 [0.0812]	11.9990 [0.0620]
Heteroskedasticity (No Cross Terms)	49.7015 [0.4053]	36.0458 [0.8979]	56.5179 [0.1868]
Heteroskedasticity (With Cross Terms)	105.0721 [0.0597]	67.8142 [0.9010]	93.8465 [0.2169]

Notes: Diagnostic tests: Serial Correlation = Lagrange Multiplier (LM) test of VEC residual serial correlation; Normality = Based on Cholesky of covariance (Lutkepohl) of VEC residuals; and Heteroskedasticity = Heteroskedasticity test of VEC residual. The figures in […] refer to the probabilities.

4.2.5 Granger Causality and Diagnostic Tests Based on VAR of First Difference for Energy Supply with CO_2 Variable

Granger causality test in VAR of first difference is conducted for energy supply of petroleum and hydropower to determine the short run causality relationships. As depicted in Table 4.14, it demonstrates that short run causal relationship do not exists between GDP, energy supply (petroleum and hydropower) and CO_2 emission in Malaysia, indicating that petroleum and hydropower consumption does not help to predict GDP in the short and long run. However, both petroleum and hydropower supply does not have influence towards GDP in the future (beyond the sample).

Table 4.14: Granger Causality Test in VAR of First Difference Results for Energy Supply with CO_2 Variable

Energy Demand	Dependent Variables	χ^2-statistic (p-value)		
		ΔGDP	ΔPET	ΔCO2
	ΔGDP	-	0.5080(0.4760)	1.3040(0.2535)
Petroleum	ΔPET	0.1756(0.6752)	-	0.4754(0.4905)
	ΔCO2	1.7043(0.1917)	0.9913(0.3194)	-
		ΔGDP	ΔHYD	ΔCO2
	ΔGDP	-	0.0361(0.8494)	1.0606(0.3031)
Hydropower	ΔHYD	0.0616(0.8041)	-	0.0082(0.9278)
	ΔCO2	1.0765(0.2995)	0.5625(0.4532)	-

Notes: "Δ" is the first different operator. Asterisks (**) indicate statistical significance at 5 per cent level.

Table 4.15 reports the diagnostic tests conducted to check the robustness of model specification. First, the LM test for residual serial correlation finds no evidence of serial correlation. The residuals are also found to be multivariate normal. Null hypothesis of normality is failed to be rejected for Jarque-Bera test (except petroleum supply). Besides that, the heteroskedasticity of residuals are also failed to be rejected for both with and without cross terms. In short, the VAR model passes all the diagnostic tests without reservation.

Table 4.15: Diagnostic Tests for VAR of First Difference Results for Energy Supply with CO_2 Variable

Tests	Energy Supply by Petroleum	Energy Supply by Hydropower
Serial Correlation	2.8192	8.4505
	[0.9710]	[0.4895]
Normality – Jarque-Bera	12.9476	10.1733
	[0.0439]	[0.1175]
Heteroskedasticity (No Cross Terms)	49.6233	42.6354
	[0.0649]	[0.2072]
Heteroskedasticity (With Cross Terms)	69.9222	62.6257
	[0.0713]	[0.1969]

Notes: Diagnostic tests: Serial Correlation = Lagrange Multiplier (LM) test of VAR residual serial correlation; Normality = Based on Cholesky of covariance (Lutkepohl) of VAR residuals; and Heteroskedasticity = Heteroskedasticity test of VAR residual. The figures in […] refer to the probabilities.

4.2.6 Variance Decomposition Test Results for Energy Supply with CO_2 Variable

Although the Granger causality test provides a rich framework in which causality can be tested, the test is strictly limited to within the sample period testing. Meanwhile, VDC is able to measure the strength of the variables while providing the dynamic properties of the system beyond the sample (Masih and Masih, 1996b; Baharumshah et al., 2006). We rely on VDC to gauge the strength of the causal relationship among GDP, energy supply by fuel types and CO_2 emission. Results of the VDC are given in Table 4.16. The major findings are discussed as follows.

In the case of oil and coal supply trivariate models, GDP seems to be the most interactive variable in the system. For example, in the case of oil supply, the VDC shows that a total of 98 per cent of the forecast error variance can be explained by oil supply (35 per cent) and CO_2 emissions (63 per cent) at the end of the 48 years horizon. This provides evidence for strong direct causality originating from energy supply (oil and coal) and CO_2 emission to GDP on the entire forecast horizon. Furthermore, gas supply seems to be the most interactive variable in the gas supply trivariate system. The VDC shows that almost 70 per cent of the forecast error variance can be explained by GDP (25 per cent) and CO_2 (45 per cent) at the end of the 48 years horizon. This provides there is an impact of GDP and CO_2 emission to gas supply.

To determine the impact of causality, as previous table, we follow the suggestion by Belsley et al. (2004) of 15 per cent. We found that there is an impact from GDP to CO_2 emissions in the case of petroleum and hydropower supply. The direct causality originating from petroleum and hydropower to CO_2 emissions are not considered a significant causality in this study.

The results of the VDC analysis in Table 4.16 reveal that supply of coal and oil are relatively more important than other energy supply (petroleum, gas and hydropower). Specifically, approximately a total of 67.5 per cent of the variation in economic growth can be explained by both oil (34.5 per cent) and coal (33 per cent). However, the supply of gas, petroleum and hydropower only justify about 2.5 per cent of the variation in Malaysia's economic growth at the end of the 48 year horizon. This finding has the same results as bivariate energy supply model.

Besides that, approximately 63.9 per cent of future changes in GDP are due to changes in CO_2 emission for oil supply model and 47.4 per cent of future changes in GDP are due to changes in CO_2 emission for coal supply model, respectively. While VDC is not in line with causality interplay, it does give a view beyond the sample period, which is an important indication for policy impetus. According to BP Statistical Review (2014b), global CO_2 emissions from fossil fuels may be 29 per cent higher in 2035 as compared to 2012, as a consequence of coal consumption in rapidly growing economies. In the meantime, the GHG intensity of oil extraction and production looks set to increase, with the move towards resources that are harder to access. This will directly or indirectly influence economic growth in the future.

Table 4.16: Variance Decomposition Test Results for Energy Supply with CO_2 Variable

Percentage of variations in	Horizon	Due to innovation in: ΔGDP	ΔOIL	ΔCO2
A. Energy Supply by Oil				
Years Relative Variance in: ΔGDP	1	**100.00**	0.00	0.00
	4	**85.75**	3.25	11.00
	8	**45.49**	16.49	38.02
	12	**23.80**	24.62	51.58
	24	**6.27**	32.04	61.69
	48	**1.57**	34.51	63.93
Years Relative Variance in: ΔOIL	1	13.29	**86.71**	0.00
	4	32.05	**67.52**	0.43
	8	37.46	**55.81**	6.73
	12	37.93	**41.66**	20.41
	24	23.20	**14.43**	62.37
	48	7.09	**14.40**	78.51
Years Relative Variance in: ΔCO2	1	36.66	1.18	**62.16**
	4	40.15	0.57	**59.28**
	8	28.77	2.66	**68.57**
	12	19.99	6.66	**73.35**
	24	8.13	16.21	**75.66**
	48	2.67	24.32	**73.19**
		ΔGDP	**ΔPET**	**ΔCO2**
B. Energy Supply by Petroleum				
Years Relative Variance in: ΔGDP	1	**100.00**	0.00	0.00
	4	**92.92**	0.52	6.55
	8	**89.42**	0.30	10.28
	12	**88.25**	0.25	11.50
	24	**87.14**	0.19	12.67
	48	**86.61**	0.17	13.22
Years Relative Variance in: ΔPET	1	5.33	**94.67**	0.00
	4	5.62	**92.12**	2.26
	8	6.31	**91.24**	2.44
	12	6.89	**90.58**	2.53
	24	8.35	**88.91**	2.74
	48	10.35	**86.61**	3.04
Years Relative Variance in: ΔCO2	1	44.38	0.12	**55.50**
	4	62.05	2.64	**35.31**
	8	70.93	1.73	**27.33**
	12	74.79	1.32	**23.89**
	24	79.21	0.84	**19.94**
	48	81.62	0.58	**17.79**

Note: The column in bold represents their own shock.

Table 4.16: Variance Decomposition Test Results for Energy Supply with CO_2 Variable (Continued)

Percentage of variations in	Horizon	Due to innovation in: ΔGDP	ΔGAS	ΔCO2
C. Energy Supply by Gas				
Years Relative Variance in: ΔGDP	1	**100.00**	0.00	0.00
	4	**99.69**	0.21	0.09
	8	**99.58**	0.29	0.14
	12	**99.54**	0.31	0.15
	24	**99.51**	0.33	0.16
	48	**99.49**	0.35	0.17
Years Relative Variance in: ΔGAS	1	0.69	**99.31**	0.00
	4	8.95	**76.25**	14.80
	8	16.75	**54.03**	29.22
	12	19.51	**45.50**	34.99
	24	22.74	**35.58**	41.69
	48	24.55	**30.00**	45.45
Years Relative Variance in: ΔCO2	1	34.73	3.58	**61.70**
	4	43.41	5.85	**50.75**
	8	37.81	12.80	**49.39**
	12	35.32	15.69	**48.99**
	24	32.35	19.16	**48.49**
	48	30.63	21.17	**48.20**
		ΔGDP	**ΔCOAL**	**ΔCO2**
D. Energy Supply by Coal				
Years Relative Variance in: ΔGDP	1	**100.00**	0.00	0.00
	4	**78.17**	10.58	11.25
	8	**49.86**	21.98	28.16
	12	**37.36**	26.70	35.94
	24	**25.02**	31.13	43.85
	48	**19.60**	32.98	47.42
Years Relative Variance in: ΔCOAL	1	14.29	**85.71**	0.00
	4	24.47	**74.00**	1.53
	8	23.99	**69.68**	6.34
	12	22.74	**66.11**	11.15
	24	19.94	**59.26**	20.80
	48	17.64	**53.73**	28.63
Years Relative Variance in: ΔCO2	1	39.95	4.98	**55.07**
	4	44.46	12.50	**43.04**
	8	35.73	18.19	**46.07**
	12	30.39	21.59	**48.03**
	24	23.28	26.25	**50.47**
	48	19.22	29.07	**51.71**

Note: The column in bold represents their own shock.

Table 4.16: Variance Decomposition Test Results for Energy Supply with CO_2 Variable (Continued)

Percentage of variations in	Horizon	Due to innovation in: ΔGDP	ΔHYD	ΔCO2
E. Energy Supply by Hydropower				
Years Relative Variance in: ΔGDP	1	**100.00**	0.00	0.00
	4	**94.16**	0.10	5.74
	8	**89.23**	0.65	10.12
	12	**87.05**	1.12	11.83
	24	**84.84**	1.72	13.45
	48	**83.81**	2.00	14.19
Years Relative Variance in: ΔHYD	1	0.14	**99.86**	0.00
	4	0.66	**99.31**	0.03
	8	1.64	**98.30**	0.06
	12	2.61	**97.20**	0.19
	24	4.97	**94.40**	0.63
	48	7.89	**90.91**	1.20
Years Relative Variance in: ΔCO2	1	38.77	0.67	**60.57**
	4	53.96	1.10	**44.94**
	8	63.32	1.93	**34.75**
	12	67.88	2.16	**29.96**
	24	73.25	2.31	**24.44**
	48	76.13	2.38	**21.49**

Note: The column in bold represents their own shock.

4.3 Energy Consumption

4.3.1 Unit Root Tests Results for Energy Consumption

As mentioned in previous section, ADF unit root test and KPSS stationary test are applied to determine the order of integration of variables of study for GDP, all fuel type of energy consumption and CO_2 emissions in Malaysia. Six variables were included in this estimation, namely gross domestic product (GDP), oil and petroleum products (OIL), natural gas (GAS), coal and coke (COAL), electricity (ELECT) and carbon dioxide (CO2) emissions.

The results of ADF unit root test and KPSS stationary test are shown in Table 4.17. The results of ADF unit root test showed that all the variables at the level form are non-stationary at 5 per cent significant level. On the other hand, the null hypothesis of all the variables is rejected except for ELECT at first difference form viewing that all test statistics are greater than the critical value at 5 per cent level of significance. In view of this, the ADF unit root test results indicate that the all the variables in this energy consumption model are in *I(1)* processes except ELECT.

The results of KPSS stationary test as illustrated in Table 4.17 as well. All the variables except GDP are non-stationary in the level form at 5 per cent level of significance. However, all the variables of energy consumption model are found to be stationary at the first difference form as we cannot reject the null hypothesis of stationary.

According to Tang (2008), KPSS stationary test has its superior properties in a small sample size and is able to distinguish between unit root and a near unit root process which makes KPSS stationary test estimation result more reliable than ADF unit root test. In the case of ELECT, we can conclude that ELECT is stationary at first difference form. As a conclusion, the six variables, namely GDP, OIL, GAS, COAL, ELECT and CO2 are stationary at *I(1)*. Since all the results are stationary at *I(1)*, thus the next step is to proceed to the cointegration test.

Table 4.17: Unit Root Tests Results for Energy Consumption

	ADF		**KPSS**	
	Intercept	**Trend and Intercept**	**Intercept**	**Trend and Intercept**
		Level		
GDP	-	-2.1316[0]	-	0.0891[3]
OIL	-	-0.5935[0]	--	0.1516[4]**
GAS	-	-2.7641[1]	-	0.1513[4]**
COAL	-	-3.3446[1]	-	0.1890[2]**
ELECT	-	-2.7256[3]	-	0.1472[4]**
CO2	-	-1.7651[0]	-	0.1591[2]**
		First Differences		
ΔGDP	-5.1206[0]**	-	0.0905[3]	-
ΔOIL	-4.6120[0]**	-	0.2896[2]	-
ΔGAS	-3.3933[1]**	-	0.3275[3]	-
ΔCOAL	-3.5857[1]**	-	0.3586[6]	-
ΔELECT	-1.5708[3]	-	0.2564[4]	-
ΔCO2	-4.5870[1]**	-	0.2244[7]	-

Notes: "Δ" is the first different operator. Asterisks (**) indicate statistical significance at 5 per cent level. Figures in […] are the lag lengths. The asymptotic and finite sample critical value for ADF is obtained from MacKinnon (1996). The ADF test examines the null hypothesis of a unit root against the stationary alternative. The KPSS test critical values are obtained from Kwiatkowski *et al.* (1992, Table 1, p.166). KPSS tests the null hypothesis that the series is stationary against the alternative hypothesis of a unit root.

4.3.2 Johansen-Juselius Cointegration Test Results for Energy Consumption

Since the unit root and stationary tests results showed that the series have the same order of integration, hence, Johansen-Juselius cointegration test introduced by Johansen and Juselius (1990) is conducted in this study. Johansen-Juselius cointegration test will test on the existence of long run relationship among the variables of study. Before applying the test, the optimum lag order (k) for the VAR to be applied in each cointegration test is determined. We determine the lag order using the information provided by the SIC.

The Johansen procedures employs two likelihood ratio test statistic (LR) in order to investigate the number of cointegrating factor exist. These two tests are trace test and maximum eigenvalue (λ_{max}) test. From Table 4.18, only trace test statistic for gas consumption is more than the critical value at 5 per cent significant level. This indicates a rejection for the null hypothesis of no cointegrating factor ($r = 0$) for trace test. On the other hand, all energy domains are not rejected at 5 per cent significant level for both trace and λ_{max} test.

The results suggest that there is a long run relationship present in the energy consumption by gas in Malaysia and its determinants which consists of GDP, gas consumption and CO_2 emissions as Cheung and Lai (1993) mentioned the trace test provides more robust results than λ_{max} of the same procedure. Therefore, a long run stable linear equilibrium relationship is said to exist among the variables for gas consumption. Besides that, the results show that there is no long run relationship between GDP, energy consumption (oil, coal and electricity) and CO_2 emission.

Table 4.18: Johansen-Juselius Cointegration Test Results for Energy Consumption

		λmax		Trace	
Null	**Alternative**	**Unadjusted**	**95% C.V**	**Unadjusted**	**95% C.V**
			Energy Consumption by Oil		
			k = 1 r = 0		
r = 0	r = 1	12.6352	21.1316	16.6847	29.7971
r ≤ 1	r = 2	3.5216	14.2646	4.0495	15.4947
r ≤ 2	r = 3	0.5279	3.8415	0.5279	3.8415
			Energy Consumption by Gas		
			k = 2 r = 1		
r = 0	r = 1	19.6014	25.8232	43.8222**	42.9153
r ≤ 1	r = 2	13.9448	19.3870	24.2208	25.8721
r ≤ 2	r = 3	10.2760	12.5180	10.2760	12.5180
			Energy Consumption by Coal		
			k = 1 r = 0		
r = 0	r = 1	19.5689	25.8232	37.9730	42.9153
r ≤ 1	r = 2	13.5876	19.3870	18.4041	25.8721
r ≤ 2	r = 3	4.8165	12.5180	4.8165	12.5180
			Energy Consumption by Electricity		
			k = 1 r = 0		
r = 0	r = 1	15.1083	21.1316	21.6261	29.7971
r ≤ 1	r = 2	3.7562	14.2646	6.5178	15.4947
r ≤ 2	r = 3	2.7616	3.8415	2.7616	3.8415

Notes: k is the lag length and r is the cointegrating vector and r is number of cointegrating vectors that are significant under both tests. Asterisks (**) denote significance at 5 per cent level.

4.3.3 Normalizing the Cointegrating Vector for Energy Consumption

The next step after confirming a long-term equilibrium relationship in the cointegration test is to obtained cointegrating vector with respect to the dependent variable (GDP). This allows us to acquire the long-term estimates for the independent variables. There is only one significant vector detected and do not have the problem of identification of the equation that represents the GDP. Table 4.19 reports the long run parameters of the model. The result shows a positive relationship between energy consumption (gas), CO_2 emissions and GDP. The estimated coefficient of gas consumption is 0.0002 and CO_2 emission is 0.96. These findings suggest that 1 per cent increase in gas consumption will result in 0.0002 per cent increase in GDP, and 1 per cent increase in CO_2 emission will result in 0.96 per cent increase in GDP. These results are similar with findings in previous studies by Ang (2008) and Begum et al. (2015) which shows that there is a positively relationship between GDP, energy consumption and CO_2 emission in Malaysia.

Table 4.19: Normalizing the Cointegrating Vector for Energy Consumption

Variables	GDP	Energy Consumption	CO2
Energy Consumption by Gas	1.0000	0.0002 (0.0223)	0.9584 (0.2027)

Note: The estimated coefficient was obtained by normalizing the GDP variable. The number in (…) denotes the t-statistics.

4.3.4 Granger Causality and Diagnostic Tests Based on VECM for Energy Consumption

Table 4.20 reports the results of Granger causality test based on VECM which contains the ECT measuring the long run disequilibrium. Given the presence of a unique and single cointegrating vector revealed by the cointegation test, this provides Malaysia's gas consumption with one ECT to construct. The estimated coefficient of ECT for gas consumption is -0.6267 and is statistically significant at 5 per cent level as its t-sttatistic is -3.9795 which is smaller than the critical value of -1.96. The speed of adjustment is 62.67 per cent per year, indicating that Malaysia will need around 1.60 years or 1 year and 7 months for energy consumption by gas to adjust back to equilibrium whenever disequilibrium happens. ECT suggests that GDP solely bears the brunt of short run adjustment to bring about the long run equilibrium in gas consumption. In other words, GDP functions as the initial receptor of any exogenous shocks that distort the equilibrium system. Furthermore, the ECT result shows that there is a long run causality running from energy consumption by gas and CO_2 emission to GDP, consistent with the finding of Ang (2008); Lean and Smyth (2010a) as well as Pao and Tsai (2010) which showed that long run causality existed from energy/electricity consumption and CO_2 emissions to GDP.

Table 4.20 summarises the results of Granger causality for variables of study (GDP, gas consumption and CO_2). In VECM, it is the short run or temporal causality relationship that is being investigated. There is a unidirectional causal relationship from energy consumption by gas to GDP without any feedback effect (GAS → GDP). Similarly, Chang (2010) found that there is a short run relationship from natural gas consumption to GDP. Besides that, there is also unidirectional causal relationship from CO_2 emission to GDP without any feedback effect (CO2 → GDP). This short run causality result is consistent with the finding by Pao and Tsai (2010) who found that there was a strong short run causality running from emissions to real output. Apart from Pao and Tsai (2010), Cowan et al. (2014) also proved that there is a unidirectional causality from CO_2 to GDP in Russia.

Table 4.20: Granger Causality Test Based on VECM for Energy Consumption

Energy Consumption	**Dependent Variables**	**χ^2-statistic (p-value)**			**ECT**	
		ΔGDP	ΔGAS	ΔCO2	Coefficient	T-Statistic
Gas	ΔGDP	-	28.1025** (0.0000)	18.2416** (0.0001)	-0.6267**	-3.9795
	ΔGAS	0.0330 (0.9836)	-	1.4500 (0.4843)	-0.4236	-0.3684
	ΔCO2	0.6420 (0.7254)	1.5193 (0.4678)	-	-0.2643	-0.9665

Notes: "Δ" is the first different operator. Asterisks (**) indicate statistical significance at 5 per cent level.

Table 4.21 reports the results of a battery of diagnostic checking that was conducted to ensure the efficiency and reliability of the model. The results reveal that model has passed serial correlation test and heteroskedasticity test as we could not reject the null hypotheses. On the other hand, the model suffers from normality test problem, but on a general note, the model is able to produce efficient and reliable estimate having passed the major diagnostic tests.

Table 4.21: Diagnostic Tests for VECM Results for Energy Consumption

Tests	Energy Consumption by Gas
Serial Correlation	4.7799
	[0.8531]
Normality – Jarque-Bera	23.1489
	[0.0007]
Heteroskedasticity (No Cross Terms)	70.4557
	[0.8543]

Notes: Diagnostic tests: Serial Correlation = Lagrange Multiplier (LM) test of VEC residual serial correlation; Normality = Based on Cholesky of covariance (Lutkepohl) of VEC residuals; and Heteroskedasticity = Heteroskedasticity test of VEC residual. The figures in […] refer to the probabilities.

4.3.5 Granger Causality and Diagnostic Tests Based on VAR of First Difference for Energy Consumption

Other than investigating long and short run Granger causality relationship among the variables of study via VECM (for gas consumption model), Granger causality test based on VAR of first difference is conducted to determine the existence of short run causality relationship between GDP, energy consumption by oil, coal and electricity and CO_2 emission.

As illustrated in Table 4.22, the results clearly show the existence of a short run unidirectional causality relationship from energy consumption by electricity to CO_2 emission where the p-value is less than 5 per cent significant level. Similarly, Cowan et al. (2014) and Shahbaz et al. (2014) found that there is unidirectional relationship from electricity consumption to CO_2 emissions. Furthermore, there is no short run causal relationship between GDP, energy consumption by oil and coal and CO_2 emission where the results are not statistically significant at 5 per cent level. In this study, there are no evidence of any short and long run causal relationship between GDP, oil and coal consumption, and CO_2 emissions within sample, but there is evidence of impact causality between the variables beyond the sample (see next paragraph: variance decomposition test). This in term means that oil and coal consumption does not help to predict GDP in the short and long run but do have impact in the future or beyond the sample.

Table 4.22: Granger Causality Test in VAR of First Difference Results for Energy Consumption

Energy Consumption	Dependent Variables	χ^2-statistic (p-value)		
		ΔGDP	ΔOIL	ΔCO2
	ΔGDP	-	1.2258(0.2682)	0.1317 (0.7167)
Oil	ΔOIL	0.3665(0.5449)	-	0.1625(0.6869)
	ΔCO2	1.1719(0.2790)	2.8651(0.0905)	-
		ΔGDP	ΔCOAL	ΔCO2
	ΔGDP	-	0.3827(0.5362)	1.4468(0.2290)
Coal	ΔCOAL	0.0223(0.8813)	-	0.6827(0.4087)
	ΔCO2	1.4071(0.2355)	0.2589(0.6109)	-
		ΔGDP	ΔELECT	ΔCO2
	ΔGDP	-	2.2763(0.1314)	0.1483(0.7002)
Electricity	ΔELECT	2.6136(0.1059)	-	1.0719(0.3005)
	ΔCO2	0.0122(0.9120)	4.8582**(0.0275)	-

Notes: "Δ" is the first different operator. Asterisks (**) indicate statistical significance at 5 per cent level.

Subsequently, a series of diagnostic tests are imposed to ensure the robustness of estimated model. First, the LM test for residual serial correlation finds no evidence of serial correlation and the residuals are also multivariate normal. Null hypothesis of normality is failed to be rejected. Besides that, the heteroskedasticity of residuals is also failed to be rejected for both with and without cross terms. Hence, the VAR model passes all the diagnostic tests without reservation.

Table 4.23: Diagnostic Tests for VAR of First Difference Results for Energy Consumption

Tests	Energy Consumption by Oil	Energy Consumption by Coal	Energy Consumption by Electricity
Serial Correlation	5.2668	10.5126	12.3311
	[0.8105]	[0.3106]	[0.1953]
Normality – Jarque-Bera	6.4763	9.6603	10.6142
	[0.3720]	[0.1397]	[0.1011]
Heteroskedasticity (No Cross Terms)	33.6405	41.9343	33.8981
	[0.5813]	[0.2291]	[0.5689]
Heteroskedasticity (With Cross Terms)	57.5117	71.7534	52.7504
	[0.3465]	[0.0534]	[0.5227]

Notes: Diagnostic tests: Serial Correlation = Lagrange Multiplier (LM) test of VAR residual serial correlation; Normality = Based on Cholesky of covariance (Lutkepohl) of VAR residuals; and Heteroskedasticity = Heteroskedasticity test of VAR residual. The figures in […] refer to the probabilities.

4.3.6 Variance Decomposition Test Results for Energy Consumption

In order to gauge the relative strength of the variables and the transmission mechanism responses, we shock the system and partition the forecast error variance decomposition for each of the variables in the system. VDC test is employed in this study as previously mentioned in Chapter Three. Results of the VDC are given in Table 4.24.

CO_2 emission seems to be the most interactive variable in the system except for energy consumption by gas. For example, in the case of oil consumption, the VDC shows that approximately a total of 96 per cent of the forecast error variance can be explained by GDP (20 per cent) and energy consumption by oil (76 per cent) at the end of the 48 years horizon for the case of oil consumption. In the case of electricity consumption, VDC shows that a total of 84 per cent of the forecast error variance can be explained by GDP (17 per cent) and electricity consumption (67 per cent) at the end of the 48 years horizon. This provides evidence for strong direct causality originating from GDP and energy consumption (oil and electricity) to CO_2 emission on the entire forecast horizon

Following the study of Belsley et al. (2004) who set 15 per cent as a cut off line for VDC, there is only evidence direct causality originating from CO_2 emissions to GDP for gas consumption and a direct causality running from GDP to CO_2 emissions for coal consumption. The impact of gas consumption towards GDP and coal consumption to CO_2 emissions are not considered a significant causality in this study.

In addition, the results in Table 4.24 reveal that oil and electricity consumption are relatively more important than other energy consumption (gas and coal). Particularly, approximately 73.6 per cent of future changes in economic growth are due to changes in oil consumption, and approximately 68.7 per cent of future changes in economic growth are due to changes in electricity consumption. However, the consumption of gas and coal only justify about 12 per cent of the variation in Malaysia's economic growth at the end of the 48 year horizon.

Besides that, approximately 78.7 per cent of the variation in economic growth can be explained by CO_2 emission for gas consumption model. Nonetheless, CO_2 emissions by oil, coal and electricity consumption models only justify about 21.5 per cent of the variation in Malaysia's economic growth at the end of the 48 year horizon.

In viewing that Malaysia will transform to a fully industrialised nation in the future, rapid industrialisation needs more energy consumption (Ang, 2008) and as such, it will have negative impacts on the environment. Such situation is due to the reason that Malaysia is a country that heavily dependent on fossil fuels (Oh et al., 2010). In other words, increase in Malaysia's GDP and energy will stimulate more CO_2 emissions in the nation, especially for gas consumption such as revealed in this study.

Table 4.24: Variance Decomposition Test Results for Energy Consumption

		Due to innovation in:		
Percentage of variations in	**Horizon**	**ΔGDP**	**ΔOIL**	**ΔCO2**
		A. Energy Consumption by Oil		
Years Relative Variance in: ΔGDP	1	**100.00**	0.00	0.00
	4	**91.56**	7.71	0.73
	8	**73.21**	25.52	1.27
	12	**57.62**	40.94	1.44
	24	**34.23**	64.30	1.47
	48	**25.03**	73.59	1.38
Years Relative Variance in: ΔOIL	1	28.24	**71.76**	0.00
	4	23.08	**76.18**	0.74
	8	18.79	**80.12**	1.09
	12	15.96	**82.85**	1.19
	24	11.75	**87.04**	1.21
	48	10.25	**88.57**	1.18
Years Relative Variance in: ΔCO2	1	35.70	12.31	**51.99**
	4	49.09	24.60	**26.31**
	8	45.12	40.11	**14.77**
	12	38.06	51.74	**10.20**
	24	25.23	68.82	**5.95**
	48	19.69	75.55	**4.76**

Note: The column in bold represents their own shock.

Table 4.24: Variance Decomposition Test Results for Energy Consumption (Continued)

Percentage of variations in	Horizon	Due to innovation in: ΔGDP	ΔGAS	ΔCO2
B. Energy Consumption by Gas				
Years Relative Variance in: ΔGDP	1	**100.00**	0.00	0.00
	4	**21.03**	68.92	10.05
	8	**15.54**	44.27	40.19
	12	**12.96**	30.01	57.03
	24	**10.91**	16.26	72.83
	48	**10.19**	11.12	78.69
Years Relative Variance in: ΔGAS	1	14.13	**85.87**	0.00
	4	10.55	**88.82**	0.63
	8	11.81	**86.76**	1.43
	12	12.17	**85.97**	1.86
	24	12.61	**84.73**	2.66
	48	12.85	**83.98**	3.17
Years Relative Variance in: ΔCO2	1	28.46	4.36	**67.18**
	4	15.98	22.90	**61.12**
	8	12.71	18.06	**69.23**
	12	11.55	14.82	**73.63**
	24	10.48	10.91	**78.61**
	48	10.02	9.03	**80.95**
		ΔGDP	**ΔCOAL**	**ΔCO2**
C. Energy Consumption by Coal				
Years Relative Variance in: ΔGDP	1	**100.00**	0.00	0.00
	4	**93.16**	0.07	6.77
	8	**88.92**	0.40	10.68
	12	**87.20**	0.60	12.20
	24	**85.48**	0.81	13.71
	48	**84.66**	0.91	14.43
Years Relative Variance in: ΔCOAL	1	6.01	**93.99**	0.00
	4	12.09	**83.23**	4.68
	8	18.34	**75.18**	6.48
	12	23.24	**69.52**	7.24
	24	33.09	**58.31**	8.60
	48	42.68	**47.40**	9.92
Years Relative Variance in: ΔCO2	1	41.06	5.22	**53.72**
	4	57.09	5.63	**37.28**
	8	66.34	4.18	**29.48**
	12	70.69	3.40	**25.91**
	24	75.80	2.46	**21.74**
	48	78.59	1.95	**19.46**

Note: The column in bold represents their own shock.

Table 4.24: Variance Decomposition Test Results for Energy Consumption (Continued)

Percentage of variations in	Horizon	Due to innovation in:		
		ΔGDP	ΔELEC	ΔCO2
D. Energy Consumption by Electricity				
Years Relative Variance in: ΔGDP	1	**100.00**	0.00	0.00
	4	**92.56**	6.07	1.37
	8	**70.08**	26.20	3.72
	12	**50.12**	44.75	5.13
	24	**29.75**	64.40	5.85
	48	**25.65**	68.65	5.70
Years Relative Variance in: ΔELEC	1	15.26	**84.74**	0.00
	4	5.58	**89.75**	4.67
	8	3.45	**90.09**	6.46
	12	5.02	**88.36**	6.62
	24	9.72	**84.03**	6.25
	48	12.58	**81.46**	5.96
Years Relative Variance in: ΔCO2	1	33.36	2.90	**63.74**
	4	32.81	16.01	**51.18**
	8	24.00	36.54	**39.46**
	12	18.67	50.13	**31.20**
	24	15.91	63.80	**20.29**
	48	16.70	67.38	**15.92**

Note: The column in bold represents their own shock.

CHAPTER FIVE

CONCLUSION AND POLICY RECOMMENDATIONS

5.0 Introduction

The purpose of this study is to investigate the relationship between economic growth and energies (energy supply and energy consumption) in Malaysia, as well as to chart relevant policy implications from the results. The five fuel types of energy supply which had been considered in this study are crude oil, petroleum products, natural gas, coal and coke, and hydropower. The four energy consumption by fuel types are oil and petroleum products, natural gas, coal and coke, and electricity. This study used annual observations covering the period from 1978 until 2010 (energy supply) and 1980 until 2010 (energy consumption), respectively.

The methodologies that had been employed in this study are the Augmented Dickey-Fuller (ADF) test by Dickey and Fuller (1979) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test by Kwiatkowski, Phillips, Schmidt and Shin (1992). These tests are being adopted in order to test the order of integration of variables under study. Besides that, the cointegration test adopted from Johansen and Juselius (1990) is being employed to test the long run relationship between these variables. Then, Granger causality test by Granger (1988) is also being utilised in this study to tests the direction of causality of variables, in which Granger causality test is being conducted in vector error correction model (VECM) to avoid problems of misspecification (Baharumshah and Lau, 2007). VECM is a special case of vector autoregressive (VAR) that applied cointegration to its variables. The relevant error correction term (ECT) is being included in the VAR to prevent misspecification and exclusion of important constraints. Lastly, the Variance Decomposition (VDC) test is employed to gauge the strength of the causal relationship among the variables beyond the sample.

This chapter presents the summary as well as the policy implications from the findings of this study. In addition, a few recommendations have also been identified from the estimation results of this study. The limitations of the present study and suggestions for future studies are also included in this chapter.

5.1 Summary of Findings

Some interesting results emerged from this analysis. The summaries of findings are presented according to the fuel types of energies.

5.1.1 Energy Supply

The empirical results show that there is a long run positive relationship between energy supply of oil and coal with economic growth (GDP) while no such relationship is found for other remaining domains of energy supply in Malaysia. According to Granger (1988), the existence of a long run cointegrating vector implies that there is at least one direction in Granger causality relationship. However, it does not indicate the direction of causality. So, the next step is to proceed to the Granger causality test to infer Granger causality among the variables.

The results from the Granger causality test suggest that in the long run, there is a positive causality running from energy supply of oil and coal to GDP. Moreover, the Granger causality test results also reported the existence of unidirectional causality relationship running from GDP to energy supply by petroleum and gas without any feedback in the short run. Meanwhile, there is no short run relationship in the case of energy supply by oil, coal and hydropower.

In addition, the VDC test, which tests for the relationship beyond the sample, supported that a strong direct causality originating from GDP to energy supply by oil and gas existed in Malaysia. Besides that, the results of VDC also show the impact of energy supply by coal to GDP. Furthermore, coal and oil supply are relatively more important on GDP if compare to other energy supplies. These results become important implications for policy analysts and forecasters in Malaysia.

5.1.2 Energy Supply with Pollutant Variable (CO_2 Emissions)

In the case of trivariate energy supply model, the empirical results provide supporting a long run negative relationship between GDP and energy supply (oil and gas). This finding provides the possibility that including CO_2 emission as a control variable does not fit well for this model. Other possibilities to improve this model are to include more explanatory variables or using other measurement that is more representative of pollution variable. Apart from that, there is no short run causality relationship found for trivariate energy supply model in this study.

In addition, the VDC test, which tests for the relationship beyond the sample, revealed a strong direct causality originating from energy supply and CO_2 emissions to GDP, which appeared in oil and coal supply. For energy supply by gas, the results of VDC showed that the impact of GDP and CO_2 emissions on gas supply existed. Other than that, the impact of GDP on CO_2 emissions on petroleum and hydropower supply model is also unveiled. Besides that, supply of coal and oil and CO_2 emissions for both models are relatively more important on GDP other than petroleum, gas and hydropower supply.

5.1.3 Energy Consumption

The empirical results provide support for a robust long run relationship between the gas consumption model's variables, revealing that gas consumption and CO_2 emissions are positively related to GDP in the long run. Moreover, there is a unidirectional causality relationship running from energy consumption by gas to GDP; and also from CO_2 emissions to GDP without any feedback in the short run. Meanwhile, in the short run, unidirectional causality relationship existed from energy consumption by electricity to CO_2 emissions.

Furthermore, the VDC test, which tests for the relationship beyond the sample, supported that a strong direct causality originating from GDP and energy consumption to CO_2 emissions which emerged in oil and electricity consumption. For energy consumption by gas, the results of VDC showed that there is an impact of CO_2 emissions on GDP, and also, there is an impact of GDP on CO_2 emissions in coal consumption model. Moreover, oil and electricity consumption are relatively more important on GDP on the entire horizon (48 years). In these views, caution steps need to be taken in implementing energy policy.

5.2 Policy Implications

5.2.1 Energy Supply

In view of major issues in energy such as energy security and environmental issues that have received more and more concern at a worldwide level, the empirical analysis of the relationship between energy supply and economic growth conducted in this study has bring about important implications for Malaysia's economic and energy policy. The short run causality relationship that exists from economic growth to petroleum and gas supply implies that in Malaysia, the policy of energy conservation such as energy saving, energy restrictions and supply management policies should be reinforced for a short period as growth in the economy corresponds with a high level of energy supply (Lise and Montfort, 2007; Payne, 2010).

Moreover, the empirical results proved that neutrality hypothesis is supported for other energy supply domains (oil, coal and hydropower) in the short run. This will imply that either conservative or expansive policies in relation to energy supply can be applied in short run. For example, imposing taxes to reduce oil, coal and hydropower supply or implementing a conservation policy regarding those types of energy will not harm economic growth (Shaari et al., 2013).

In the long run, a positive unidirectional causal relationship was detected originating from energy supply by oil and coal to GDP. Such finding proves that energy (oil and coal supply) acts as an engine of economic growth in the long run for Malaysia. Therefore, shocks to the energy supply by oil and coal will have a negative effect on GDP (Lee and Chang, 2005). So, the government and industries should increase the investment on energy supply (oil and coal) in order to increase the energy security in Malaysia. In the quest of achieving continuous economic growth, Malaysia needs to put more effort in increasing energy supply, especially for oil and coal while implementing national energy policies towards advanced development in the long term, especially developing the renewable energy sector. The findings discovered from the VDC supports the policy that more efforts in securing the supply of oil and coal need to be carried out as oil and coal supply are the energy supply that play an important role in the future.

Therefore, the Malaysian government should carry out energy saving measures which reduce inefficiency or unnecessary wastage of energy in the nation. Additionally, in order to meet the increasing demand of energy, energy supply infrastructure in Malaysia will need to be continuously developed. For example, Malaysian government should increase the investment in energy supply industry by intensifying energy efficiency initiatives. This could strike a balance between environmental concern, economic growth and energy security for Malaysia.

5.2.2 Energy Consumption

The findings from trivariate energy consumption model suggest that there is an existence of a positive long run causality running from gas and CO_2 emissions to GDP in Malaysia. The results also proved that short run causality running from gas to GDP, as well as from CO_2 emissions to GDP. The evidences seem to suggest that a reduction in gas consumption can be harmful to Malaysia's economic growth (Shaari et al., 2013). In addition, the causality relationship from CO_2 emissions to

GDP indicated that the decline in environmental quality may exert negative externalities to the economy. The negative externalities will negatively affect the tourism sector and also affect human health and thereby reducing productivity and growth in the long run (Ang, 2008; Chebbi, 2009; Pao and Tsai, 2010; Alkhathlan and Javid, 2013).

On the other hand, short run causality running from electricity to CO_2 emissions also exists in Malaysia. The evidence seems to suggest that CO_2 emissions in Malaysia depend on electricity in the short run as the electricity in Malaysia is generated by natural gas (52 per cent) and coal (26.7 per cent) in 2011 (MEIH, 2013). Generally, energy that is generated by fossil fuels sources (natural gas, coal and oil) can cause environmental pollution and as for Malaysia, such situation is similar with the experience of many developing countries. Therefore, Malaysian government should develop policies that aim at reducing CO_2 emissions to protect the environment for future generations and at the same time does not harm the economy.

In future, Malaysia will consume more energy due to rapid industrialisation which is required to become a fully industrialised country (Ang, 2008). Thus, Malaysia must determine ways to achieve economic growth and at the same time can minimise energy consumption and reduce CO_2 emissions. The empirical findings from VDC show that oil and electricity consumption are relatively more important than other energy consumption (gas and coal). Therefore, the Malaysian government needs to come up with energy policies, especially for oil and electricity that take into account the relationship between development and CO_2 emissions reduction (Niu et al., 2011).

5.3 Limitations and Recommendations for Future Study

In this study, the annual observations from 1978 to 2010 for energy supply and from 1980 to 2010 for energy consumption were used. The usage of such low frequency data had limited the results that can be obtained from a mixture of various frequency input. In the case of applying quarterly or monthly data, the findings could be analysed in a more in depth level, but the available data in high frequency are limited in Malaysia.

The second limitation of this study is the number of variables included in the model estimation in which only three variables were utilised, namely GDP, disaggregate energies (energy supply and energy consumption) and CO_2 emissions to analyse the energy-GDP causal relationship. In reality, there are more variables that can be included in the empirical model to analyse this relationship. For example, future studies can include variables such as energy price, technology innovation and labour force. Therefore, it is suggested that more variables could be included for future studies.

Moreover, this study adopted the time series approach in analysing the energy-GDP relationship but in future, different tests can be employed to test the energy-GDP relationship. For example, future studies may implement the panel data techniques to examine energy-GDP relationship or to involve more countries, such as Association of Southeast Asian Nations (ASEAN) countries in examining energy-

GDP relationship at a regional level in which panel estimation is able to pool the cross-section and time series data.

Although the objectives of this study have been achieved, but there are still rooms for improvement in examining the energy-GDP relationship. In future studies, the scope can be broadened to include sectoral energy supply/consumption. This can provide insights as to which sub sector of energy is driving the growth rate in Malaysia. Such study is more in depth and will provide more information to policy makers to recommend resolutions to energy issues.

5.4 Concluding Remarks

The aim of this study is to understand the relationship between disaggregate energies (energy supply and energy consumption) and economic growth in Malaysia, which include CO_2 emissions as a control variable. The period of study covers from 1978 until 2010 for energy supply and from 1980 until 2010 for energy consumption. All disaggregate energies employed annual data in their model estimations.

In particular, energy supply and consumption provide mix results for short run causality relationship, but there is an identical causality running from energy (oil and coal supply; gas consumption) and is positively related to GDP in the long run. This empirical result proves that Malaysia is an energy dependent country. Generally, increase in energy supply and consumption in Malaysia will have impact on its GDP. Energy supply and demand will increase in time with increase in population in the future yet the supply in fossil fuels is limited and is depleting.

In future, government can pay attention renewable energy as one of the alternative energy that can solve energy security issues and at the same to mitigate climate deterioration. Malaysia must increase its efficiency in energy supply in order to meet the high demand of energy in future. Therefore, the Malaysia government needs to introduce energy policies that increase energy supply efficiency and at the same time the policies should not hinder the Malaysian economic growth and CO_2 emissions reduction.

In conclusion, Malaysia should introduce more programs or projects to improve the efficiency of energy use and reduce CO_2 emissions. Continuous research, development and innovation should be the priority to increase diversification of the energy industry, increase exploration for new energy resources, enhance production from known reserves and encourage the use of renewable energy resources. In addition, the government can develop innovative energy use technology, advice on environmentally friendly buildings and promote energy saving concepts to the public to improve energy use and reduce emissions.

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