LINKAGE BETWEEN MALAYSIAN ECONOMIC GROWTH AND ENERGY CONSUMPTION: THE ROLE OF TECHNOLOGY

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A research project submitted in partial fulfilment of the requirement for the degree of

BACHELOR OF ECONOMICS (HONS)
FINANCIAL ECONOMICS

UNIVERSITI TUNKU ABDUL RAHMAN

FACULTY OF BUSINESS AND FINANCE
DEPARTMENT OF ECONOMICS

APRIL 2015

DECLARATION

We hereby declare that:

(1) This undergraduate research project is the end result of our own work and that due acknowledgement has been given in the references to ALL sources of information be they printed, electronic, or personal.

(2) No portion of this research project has been submitted in support of any application for any other degree of qualification of this or any other university, or other institutes of learning.

(3) Equal contribution has been made by each group member in completing the research project.

(4) The word count of this research report is 22, 347 words.

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Date: 17th April 2015

ACKNOWLEDGEMENTS

First and foremost, we would like to express our utmost appreciation to our research supervisor, Professor Dr Choong Chee Keong, who has been genuinely supportive on our research. He is exceptionally generous in sharing his extensive knowledge in the field of financial economics with us and giving us invaluable opinions that improve the quality of this research paper. Prof. Choong never fails to meet us up for discussion despite his packed schedule and we are grateful for his admirable sense of responsibility. The completion of this paper is not possible without his guidance and encouragement.

Besides, we are thankful for this opportunity to carry out research on important issues faced by our beloved nation. This undergraduate project also helps us to brush up our critical thinking and analytical skills. On top of that, we are appreciative for all the efforts contributed by every team member and the tremendous stress endured together.

We would also like to extend our special thanks to our second examiner, Mr Cheah Siew Pong for his advices in aiding us to polish our research project. He is very sincere in providing us different point of view during our presentation. Lastly, we would like to offer our regards to Ms Vivien Wong Zi Wen for helping us in obtaining some data needed for our research. She has also provided us different perspectives on our research topic that are very useful amidst the preparation of this research paper.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This paper seeks to investigate the long run and short run linkage between Malaysian economic growth and energy consumption from 1985 to 2012. Possible energy imbalance in the near future has been a worldwide concern which is the main driver that urges us to involve ourselves in this subject field. The study continues with the inclusion of technology to examine its effect on altering the economic growth and energy consumption nexus. In other words, our purpose is to investigate whether technology can play a part in addressing the energy issue Malaysia is facing with. The employment of ARDL approach reveals stable long run relationship between energy consumption and economic growth and also technology and economic growth. Energy consumption is found to have transferred a portion of its effect on economic growth to technology when the latter is integrated into the function. This finding implies that technology is essential to stimulate growth. Our results from Granger Causality Test further provide empirical evidence which suggests that Malaysia become less energy dependent with the inclusion of technology. Hence, the incorporation of technology reduces the impact of energy consumption on growth in the long run while taking away its impact in the short run. It is concluded that while energy consumption remains important in contributing to economic growth, the role of technological advancement in refining the energy-growth linkage must be taken seriously too. Thus, designing policies on encouraging energy efficiency and stimulating technological innovation is imperative for Malaysian economic growth.

CHAPTER 1: INTRODUCTION

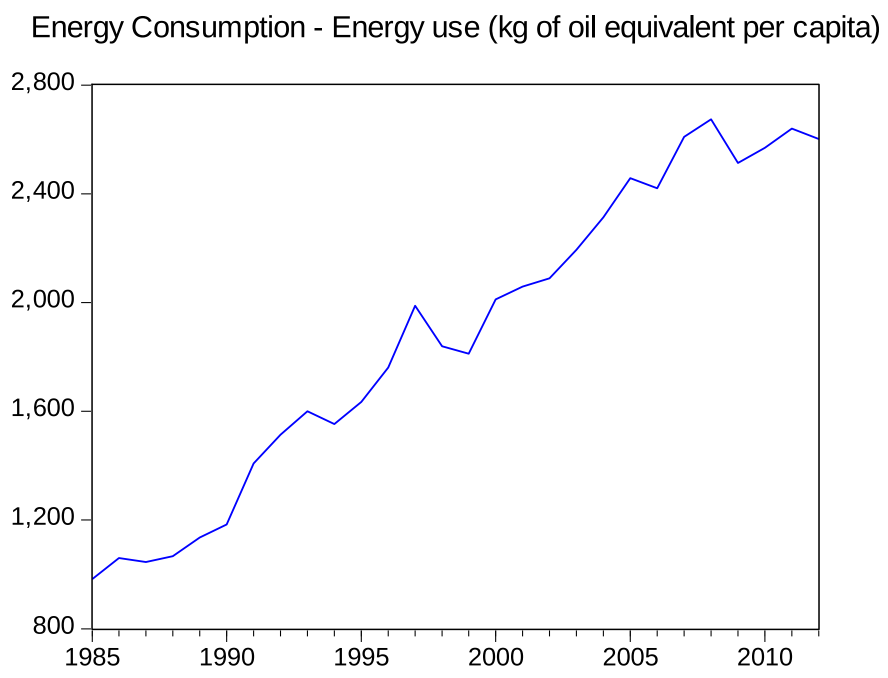
1.0 Overview

Energy consumption has been a subject of heated discussion lately on its enormous effect on GDP. Energy demand is on the rise all around the globe where the oil and gas industry continues to play its essential role in the supply side to keep the demand-supply in equilibrium. It is said that steady state economic growth needs to be complemented by a corresponding growth of energy consumption, unless the energy efficiency of production grows faster than output itself (Zon and Yetkiner, 2002). That is why energy efficiency is critical in securing optimal level of energy consumption without reducing its effect on economic growth. Moreover, inefficient use of energy would also substantially contribute to climate change (Association of Water and Energy Research Malaysia, 2012).

Malaysia is listed as the third largest energy consumer in the Association of South-East Asian Nations by the International Energy Agency. Its energy industry is found to have significant contribution to the economic growth which makes up almost 20% of total gross domestic product. Malaysia's primary energy consumption relies heavily on oil and natural gas with a combined proportion of approximately 76% of total energy consumed.

Malaysia energy consumption in 2012 recorded the highest growth of 7.5% since 2007 with transport and manufacturing sector being the largest consumers of energy. The trend of energy consumption in Malaysia has also been increasing steadily since decades ago to fuel Malaysian economic growth.

<u>Figure 1.1: Malaysia's Energy Consumption Trend from 1985 to 2012</u>



Source: World Bank Databank

Figure 1 portrays the trend of Malaysia's energy consumption starting from 1985 until 2012, where the y-axis represents the energy use (kg of oil equivalent per capita) while the x-axis represents the time period (year). From the graph, we can clearly see an upward trend in the level of energy consumption in Malaysia except for the slight decrease in year 1997/98 and 2007/08 which are the years where the Malaysia was experiencing economics turbulence.

The first energy policy in Malaysia can be traced back to 1949 where the Central Electricity Board of the Federation of Malaya (CEB) was set up to meet the upraising energy demand. It handled three massive projects which are the Connaught Bridge Power Station, the Cameron Highlands Hydroelectric Project and the development of a National Grid as proposed by the Electricity Department right after its inception (Tenaga Nasional Berhad, 2015).

The establishment of CEB had ended the era of private generators and centralised the power industry in the effort of ensuring equal opportunity for every citizen to enjoy their right in energy consumption. CEB was later renamed to National Electricity Board (NEB) in 1965, after the Malaysia achieved independence, during the "Malayanisation" process and was then being privatised and succeeded by Tenaga Nasional Berhad in 1988. As Malaysia is moving towards achieving high income nation status, the electricity demand is also growing and is projected to grow by more than 3% through 2020 (U.S. Energy Information Administration, 2014).

Electricity generation in Malaysia is mostly met by natural gas which is its second biggest primary energy consumption. Thus, efficient use of natural gas is important to maintain electricity supply. One concerning problem is that oil and natural gas field production has fallen in the midst of rising consumption, causing lesser amount of oil and natural gas left for exports. As a temporary solution, Malaysia's national oil company, Petronas is carrying out several Enhanced Oil Recovery projects to extend Malaysia's oil field production life and several deep water projects in Sabah and Sarawak. Besides, fuel diversification method is also applied through coal imports and investment in renewable energy to avoid over-dependency on oil and natural gas (U.S. Energy Information Administration, 2014).

While energy demand in Malaysia is on the climb, Malaysia economic growth is also experiencing impressive annual growth over the past few years. Back in 2009, the Prime Minister has announced the implementation of Economic Transformation Programme which includes oil, gas and energy sector as one of its National Key Economic Areas. It goes without saying that the government is aware of the importance of energy sector in lifting the country's growth. More stable energy sector would then secure more stable energy consumption.

Therefore, we are eager to test the relationship of energy consumption and economic growth in Malaysia in the past decades to understand more on their long run and short run correlation.

1.1 The Technological Factor

In this fast moving sphere of 21st century, technology is undeniably one of the most influential tools that possesses the ability to shake and shape our current and future way of living. As a fast developing Asian nation, Malaysia has increasingly given much emphasis on better power and energy management to make sure optimal energy consumption is achieved. One important reason is that all developing nation's national growth has become inextricably tied to efficiency of energy consumption (Ohri and Ohri, 2007). On top of that, energy efficiency is dependent on technological advancement which makes technological changes to have an effect on economic growth directly and indirectly. For instance, Korea was found to have 64% of its growth contributed by technological change (Molinari, Rodriguez and Torres, 2013).

We are living in a world where technology and innovation have always played a key role in moving the energy industry forward. According to Simpson (2015), technology is the application of scientific knowledge for practical purposes, especially in industry. In our context, the practical purpose is to improve energy efficiency which would then lead to economic growth. Energy efficiency is defined by the International Energy Agency (2014) as a way of managing and restraining the growth of energy consumption to deliver more output with same energy input or to deliver same output with less energy input.

As the importance of technology in promoting economic growth is getting recognized globally, developing countries have taken notes on the channels which can facilitate the inflows of such technological changes. The concept and working of technological changes in developing countries is different from that in developed countries. It is more focused on acquiring and improving technological competency which consists of mastering and improving on technologies that already exist in advanced countries rather than of innovating at frontiers of knowledge (Lall, 2000).

International trade and FDI inflows are two fundamental mechanisms responsible for the transmission of technology (World Bank, 2008). Countries can bring in new technologies through financing new investment of foreign firms in establishing local counterparts in the domestic markets. Besides, the positive spillover effects are often overwhelming as workers who received training on mastering technological know-how shift to domestic firms or set up new local venture (Glass and Saggi, 2002; Rhee, Katterback, and White, 1990). All of these will directly translate into more efficient usage of energy.

However, to merely introduce new technology to the domestic markets is not enough as economic growth can only be fuelled by new technology when and if the technology is widely diffused and used (Hall and Khan, 2002). Thus, it is more important for developing countries to highlight their rate of adoption of technology to maximize the potential benefits gained along the process.

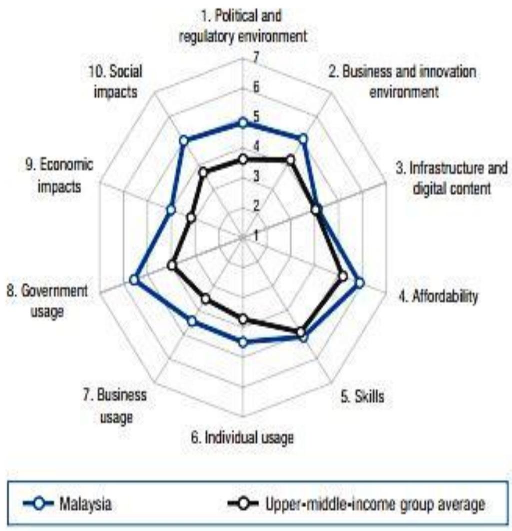
One notable factor is the education level of workers as many researchers found out that highly educated workers tend to adopt new technologies faster than the less educated ones (Welch, 1970 and Wozniak, 1984). The existing labour forces in the domestic markets need to have basic technological literacy in order to accelerate the process of adoption. Next, government also plays a crucial role in financing innovative activities and promoting pro-active technology policies on adapting and adopting existing technologies (World Bank, 2008).

While accepting technology as an essential key to stimulate impressive growth, developing countries must also properly examine its pros and cons towards domestic economy and social development. In the private sector, production and the manufacturing process have been vastly improved as advanced technologies are introduced into the production line. However, these cutting-edge machineries are also the main culprit behind the major lay off of low-skilled workers in recent decades. Nonetheless, with old jobs becoming irrelevant comes new employment opportunities for the high-skilled labours in the global tech market (Kvochko, 2013). Besides, many businesses have also chosen to go online as to reduce cost and to benefit from the convenience of less hectic operations and transactions.

Meanwhile in the public sector, the trend of establishing functional e-government has risen in the midst of technological boom and bust all around the globe. The efforts of putting government services online aim at providing a more open, more responsive and cleaner public administration. At the same time, making government services online can reduce many hectic business procedures which in turn provide a more conducive business environment to attract FDI. Despite that, the gap between the haves and the have-nots has been widened to an alarming state since the penetration of technology into our daily life. This is because of the ownership of technology of the rich and the poor differs so extensively that those who can afford get well-connected and have louder voice while those who cannot afford continue to stay unheard. Not only that, massive job replacement also take place in the public sector which worsen the already unpleasant outlook of low-skills workers.

Figure 1.2: Malaysia's Network Readiness Index 2014 Breakdown

	Rank (out of 148)	Value (1–7)
Networked Readiness Index 2014	**30**	**4.8**
Networked Readiness Index 2013 (out of 144)	30	4.8
A. Environment subindex	**24**	**5.0**
1st pillar: Political and regulatory environment	25	4.8
2nd pillar: Business and innovation environment	24	5.1
B. Readiness subindex	**59**	**5.0**
3rd pillar: Infrastructure and digital content	71	4.1
4th pillar: Affordability	48	5.9
5th pillar: Skills	67	5.1
C. Usage subindex	**30**	**4.8**
6th pillar: Individual usage	49	4.5
7th pillar: Business usage	27	4.5
8th pillar: Government usage	9	5.6
D. Impact subindex	**28**	**4.5**
9th pillar: Economic impacts	30	4.0
10th pillar: Social impacts	25	5.0



Source: The Global Information Technology Report 2014

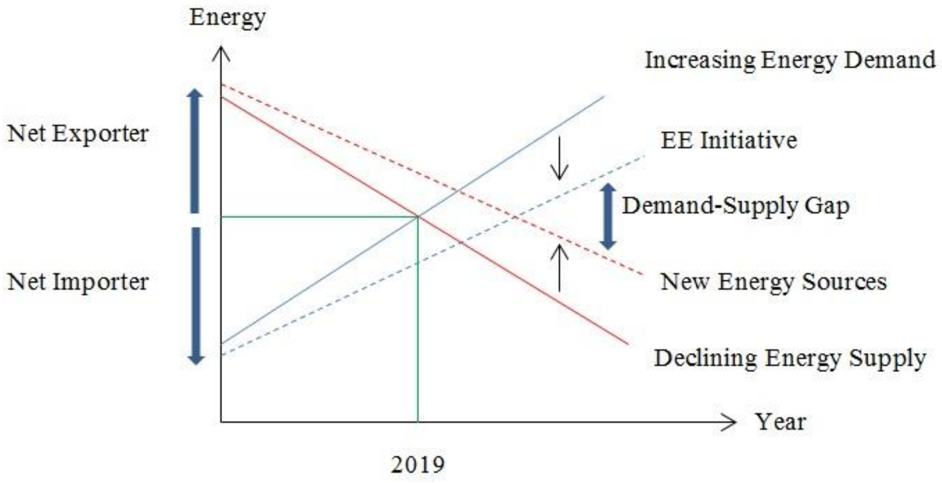
Figure 2 represents the Networked Readiness Index 2014 breakdown for Malaysia. According to The Global Information Technology Report 2014 (2014), Malaysia is ranked 30th among 148 economies, the highest ranked economy in Developing Asia. Malaysia continues to highlight high priority of this sector in the government's agenda by using ICTs extensively. Firms in private sector are putting more efforts in becoming more innovative by increasing their investment in new technologies adoption which contribute to the strong business usage ranking of 27th. Favourable environment together with an overall high level of ICT usage has resulted in high positive economic (30th) and social (25th) impacts. Nonetheless, extra investment in infrastructure and digital content are needed to ease access and stimulate even higher economic and social impacts. Still, among developing countries in ASEAN, Malaysia is, notably, the only economy that manages to rank within top 30.

Furthermore, Malaysia is expecting an ICT influx in year 2015 mainly because of the intensive funding of sustained infrastructure expansion, private sector training and research and development support (Multimedia Development Corporation, 2014). Hence, we are keen on examining how technological changes can affect the energy-growth relationship in Malaysia to understand the role of technology in structuring a favourable condition for the economy.

1.2 Problem Statement

With its growth depending so much on energy industry, ensuring proper and effective energy policies in the country is imperative for Malaysia. These functions are now carried out by the Economic Planning Unit (EPU) and Implementation and Coordination Unit (ICU). Energy demand is projected to be doubled when we reach 2030 with average energy demand growth rate of 3.6% per annum which means our country will be facing with an energy demand-supply gap after 2020 (Noruddin, 2011). Thus, the New Energy Policy is introduced in the Tenth Malaysia Plan to promote efficient utilization of energy resources to narrow down the gap. The graph below is the forecasted energy supply-demand balance in the near future:

Figure 1.3: Forecasted Trend of Malaysia's Energy Demand and Supply



Source: Tenth Malaysia Plan, 2011 – 2015

Figure 3 depicts the possible demand and supply gap which might occur after 2019 where the supply of energy drops below its demand. Noticing this as a serious problem, the government has been continuously pushing out energy efficiency initiatives to reduce energy consumption and at the same time, looking for new energy sources to overcome the issue of declining energy reserves.

Although Malaysia service sector is catching up to support 55% of Malaysia GDP, the manufacturing sector in Malaysia is still contributing to a large portion of 25% of the country's GDP. Furthermore, due to its easily exportable nature, manufacturing sector will still remain important beyond 2020 as compared to the service sector as services are not so easily exportable. At the same time, manufacturing sector depends heavily on energy consumption to convert raw materials into end products which is why it is now one of the key sectors that need improvement to avoid unnecessary wastage of energy use.

Rising energy demand is necessary for the nation development process but overusing of energy may lead to unfavourable consequences. One of the biggest concerns is the adverse environmental effect. Increasing carbon footprint is drawing attentions of environmentalists and politicians all over the world who are passionate to conserve our mother nature. According to OECD (2015), more disruptive climate change is going to take place with projected 50% increase in global greenhouse gas emission if no new policies are introduced. This is where technology comes into the picture.

Increasing productivity, lowering production cost, conserving limited energy resources and having positive impacts on the environment are the reasons why energy efficiency is so much sought after (U.S. Department of Energy, 2010). All these can be achieved with technological advancement. As announced by Prime Minister Datuk Seri Najib Tun Razak in the Copenhagen Climate Change Conference back in 2009, Malaysia is aiming to accomplish a reduction of 40% in terms of carbon emission intensity of GDP by 2020 with condition that we receive technological transfer from the developed world.

Certainly, technological advancement is not without its downside. As discussed in previous section, one pitfall of it is unemployment creation among low-skilled workers as a result of technological substitution. High-skilled labours are now more needed than ever which is causing the elimination of the low-skilled workers in virtually every industry. The good thing is that job opportunities are opened to those who possess higher skills which indirectly create new line of employment. New badges of labours complete with knowledge in operating these technologies are now shaping up our labour force in Malaysia. Besides, technological advancement can reduce environmental problem created by inefficient energy consumption.

Much has been said about the importance of energy consumption and technological advancement on affecting Malaysia's progress in achieving high income nation status. Furious debates on this topic have led to in depth examinations on both of the subject matters by researchers from all parts of the world. These researchers have put in efforts in trying to prove the existence of relationship between the two variables with economic growth. However, different studies have produced different results. There are some studies found out that there is a unidirectional causality relationship between these two variables with economic growth, either in a positive or negative way (Baily and Lawrence, 2001; Tao, 2011; Heshmati, 2013). Also, some have uncovered a bidirectional causal link and even no relationship between them (Kraemer and Dedrick, 1993; Cheng, 1995; Ghali and El-Sakka, 2004 and Shiu and Lam, 2008). The mixed results indicate the relationship between energy consumption and technology toward economic growth remains contestable. It is also found that technology might have an impact on utilizing the energy consumption level (Janulis, 2004; Røpke, Christensen and Jensen, 2010 and Tang and Tan, 2012). Thus, we are interested to prove their causality in the case of Malaysia. Detail compilation of findings from different authors would be further discussed in Chapter 2.

Up to now, not many studies have examined the relationship between energy consumption, technology, capital, labour and economic growth in the context of Malaysia. The recent global oil glut caused by supply disruptions amid geopolitical tension in the Middle East and North Africa (MENA) region and Eastern Europe continues to remind us that energy consumption cannot be omitted in promoting economic growth. While the government's relentless effort in upgrading our technological position has been a constant signal that technological changes are needed to stimulate impressive growth in Malaysia.

In short, both energy consumption and technological changes are critically important in promoting Malaysia's economic growth. Thus, the importance of knowing the relationship between the variables motivates us to perform empirical testing on these variables, especially now when Malaysia is on its path to achieving high income nation status.

1.3 Research Questions

i. What is the relationship between energy consumption and economic growth in Malaysia and how are these variables important in affecting each other?
ii. Does technology play an important role in affecting economic growth and energy consumption in Malaysia?
iii. What is the direction of causality among capital, labour, energy consumption, technology and economic growth in Malaysia?

1.4 General Objective

The problem statement that we stated above gave us a better understanding and inspiration to analyse the relationship on energy consumption and technology to economic growth. Our studies could contribute to promoting policies emphasizing on upgrading our technological readiness and enhancing energy efficiency to contribute to Malaysian economic growth.

1.5 Specific Objectives

i. To examine the linkage between energy consumption and economic growth in Malaysia from 1985 to 2012.

ii. To examine the role of technology in affecting the linkage between Malaysian economic growth and its energy consumption.

iii. To analyse the causal relationship between capital, labour, energy consumption, technology and economic growth in Malaysia.

1.6 Significance of Study

All these years, most journals and researches have put their focus on either the role of energy consumption or technology on economic growth. However, few of them put these two critical factors together to examine their combined effect. Hence, it is important to test the two factors in a same function as we can identify whether the two are complementing each other or the other way round.

In this research paper, we would like to shed light on how energy consumption affects economic growth and how technology contributes to improving energy usage and economic growth, particularly in Malaysia. It is very crucial as it might serve as an inference to support or oppose the focus government have been exerting on altering technological readiness and energy consumption level in Malaysia. If proven insignificant, unnecessary budgets and funds can be reallocated and well spent in other key areas that can better support our economic growth.

Moreover, if relationships are found to be in existence between the variables, policy makers can focus more on outlining policies to attract technology inflows to complement energy consumption efficiency and uplift our economy. As mentioned before, technological advancement can bring upon higher productivity and production as well as creating new jobs for high skilled labour. Policy makers can take note on this and design policy to upscale the skillsets our current labour force possesses. Mandatory training should be enforced to make it compulsory for workers to receive certain level of trainings. This can prepare the labour force in Malaysia to embrace the inflow of technology through various channels and minimise the substitution effect of technology inflow.

One main channel through which technology is often brought in is foreign direct investment (FDI) from advanced countries. One way of doing this is to set up more free trade zones in Malaysia to attract foreign companies to set up businesses in Malaysia. Besides, policy makers could make plans to further improve our business environment and infrastructure to attract consistent inflow of FDI which can make certain that Malaysian industries are equipped with the latest technologies. This can also ensure high energy consuming industry like manufacturing industry to better control its energy consumption level to achieve efficient usage of energy. With proper policies in place, Malaysia can be well benefited from the inflows of technology.

In short, this study aims to prove the relevance of technological advancement and energy consumption towards Malaysian economic growth both in short run and long run. Once proven, this study can provide policy makers a clear direction on whether or not the current policies involving technological readiness and energy consumption level are appropriate. The result from our study can act as a reference to reconsider the appropriateness of those policies. These are important as having wise policies on the subject matters can aid to boost Malaysian economic growth in the midst of its fight to free itself from the middle income trap and achieve high income status.

1.7 Organization of the Paper

Our paper will be divided into five parts. The remaining sections are organized as follow: Chapter 2 provides a brief review on empirical literature followed by Chapter 3 which illustrates the data sources and methodology that we used in the paper whereas Chapter 4 discusses our empirical results and result interpretation. Lastly, our paper will be finished in Chapter 5 with the conclusion of our study and policy implications.

CHAPTER 2: LITERATURE REVIEW

2.0 Relationship between Economic Growth and Energy Consumption

The important role played by economy growth and energy consumption towards a country has built up interest of numbers of economists to study on the causality between the two variables. Over the past few decades, the relationship between energy consumption and economic growth has been studied by economists from different countries in different periods. Most of the reviews show that there is relationship between growth and energy. However, by knowing only the relationship between the two variables is not sufficient. Therefore, from the past three decades, economists started to examine the direction of causal relationship between economic growth and energy consumption. Still, there are no exact and fixed results from the previous studies by every economist and it shows that there is no consensus on the direction of their causality.

2.0.1 Impact of Economic Growth towards Energy Consumption

The earliest study was done by Kraft and Kraft (1978) on the relationship between energy consumption and gross national product (GNP) in the United State from year 1947 to 1974 and the empirical evidence from this study showed that there is unidirectional causality from GNP to energy consumption. This study has encouraged many others economists to continue the study on the causality between this two variables. However, not all economists agree on Kraft and Kraft (1978) study due to the different results obtained. Despite that, there are still numbers of studies that agreed the first study is right by getting the result of unidirectional causality between growth and energy consumption.

Unidirectional causality relationship can be known as one way causal between variables, without reverse. In this case, unidirectional causality occur when causal relationship between the variables is either running from economy growth to energy consumption or from energy consumption to economy growth. In our review of the causal relationship between economy growth and energy consumption, we found that there is one way causal running from growth to energy consumption (Ghosh, 2002; Mozumder and Marathe, 2007; Yu and Choi, 1985). For example, from the research did by Ghosh (2002), the result shows that one way causal running from growth to electricity in India has caused more of the electricity been used as basic energy due to the expansion in commercial and industrial sector. Not only that, their high disposable income earned by household has encouraged them to depend more on the electric gadgets hence increase their electricity consumption. This is also supported by Akkemik and Goksal (2012), proving that there is causality running from growth to energy consumption in India. Besides, by using Vector Error Correction model (VECM), it is found that there is causality running from per capita GDP to per capita electricity consumption without feedback effect in Bangladesh (Mozumder and Marathe, 2007).

According to Abaidoo (2011), he uses Sims' (1972) test to examine the relationship between the variables in Ghanian and found out that energy consumption increased by 2 percent for every percent increase in economic growth. Not only that, by using Toda Yamamoto and Wald-test to test the causality between the two variables in Pakistan from year 1971 to year 2008, it is found that economic growth in Pakistan has leads to its electricity consumption and not vice versa (Shahbaz and Feridun, 2011). This causal relationship can be further agreed by Jumbe's (2004) researched in Malawi from year 1970 to 1999 saying that economic growth in Malawi may cause growth in energy consumption. He examines relationship between electricity consumption and overall gross domestic product (GDP), agricultural GDP and non-agricultural GDP (NGDP) and found that there is causality running from GDP to electricity and same goes to NGDP (Jumbe, 2004).

Moreover, Zahid (2008) has studied on five South Asia countries using different types of energy consumption and concluded that economic growth in Pakistan, Sri Lanka and Bangladesh is crucial to maintain high level of electricity consumption which is dependent on the growth in these three economies. Similarly, the results of unidirectional relationship running from GDP to energy in Korea and Italy obtained using vector error correction (VEC) technique also shows that economic growth in the both countries will give impact to energy consumption (Soytas and Sari, 2003). In addition, the recent study done by Kasman and Duman (2015) in Turkey, Malta, Bulgaria, Poland, Croatia, Czech Republic, Latvia, Hungary, Iceland, Lithuania, FYR of Macedonia, Romania, and other country also proves that there is one way causality running from GDP to energy consumption.

2.0.2 Impact of Energy Consumption towards Economic Growth

On the other hand, the unidirectional causal relationship between growth and energy consumption might also possibly run from energy consumption to economic growth (Shiu and Lam, 2004; Akarca and Long, 1979; Morimoto and Hope, 2004; Dergiades, Martinopoulos and Tsoulfidis, 2013). In that case, energy use is necessary to boost up their economy growth or otherwise the economic growth might be hampered due to the shortage of energy supply. For instance, energy consumption in China is vital to its country economic growth due to the positive causal relationship running from electricity consumption to real GDP (Shiu and Lam, 2004).

In addition, Moromito and Hope (2004) analysed on the causality between energy and growth in Sri Lanka from year 1960 to year 1998. The authors found that changes in electricity supply from the past as well as current gave a significant impact to real GDP. There is an extra output of Rs. 88 000–137 000 ($1120–1740) for every 1-MW h increase in electricity supply in Sri Lanka therefore the shortage of power will gives and adverse impact on its country growth.

Besides, Altinay and Karagol (2005) and Halicioglu (2011) found causal relationship running from energy consumption to income in Turkey and concluded that the supply of electricity in that country is important to prolong its growth. It can be further proven by using the case in China found by Yuan, Zhao, Yu and Hu (2007) and Shengfeng et al. (2012) which states that to avoid economic growth being hindered, it is essential for China to have sufficient energy consumption in order to boost up the growth of output.

Similarly, from the research did by Zahid (2008), there is positive causal relationship running from coal to GDP in Pakistan, from gas to GDP in Bangladesh and lastly, from petroleum to GDP in Nepal. In other words, fall in consumption of these three energies might harm their country economic growth, vice versa. Also, this one way Granger causality can be further agreed by

Wolde-Rufael's (2004) research in the case of Shanghai using different types of energies. There is empirical evidence showing that electricity, coal, coke and total energy consumption in Shanghai affected its real GDP and not vice versa.

Besides affecting economic growth directly, energy consumption can also contribute to economic growth through factor of productions such as capital and labour.

2.0.2.1 Indirect Impact through Capital

According to the research done by Zeshan and Ahmed (2013) on the relationship between energy consumption, capital stock, labour and economic growth in Pakistan covering period from 1971 to 2012 year, the author conclude that increase in capital stock will increase the energy consumption. The reason is that, in order to facilitate the new capital stock, the country requires a high level of energy. The author then further explained that the unexpected increase in capital stock will stimulate economic growth. From this study, it can conclude that energy consumption can indirectly affect economic growth through capital.

2.0.2.2 Indirect Impact through Labour

The indirect effect running from energy consumption to economic growth can also cause by labour productivity. This statement is agreed by the study done by Arnim and Rada (2011) on the relationship of energy use and labour productivity in Egypt. Increase in energy intensity is due to the increase in the use of machinery, therefore the increase the labour productivity. Based on the result found, the authors conclude that labour productivity in Egypt is driven by increased usage of energy. When labour productivity increases, it can directly enhance a country economic growth. In other words, increased in energy consumption will cause the labour productivity to increase, hence enhance the economic growth.

2.0.3 Bidirectional Causal Relationship

However, as stated above, not every study came out with the same result proving that there is unidirectional relationship between growth and energy consumption. There might be a possibility that the causality between the two variables is running in both directions (Nanthakumar and Subramaniam, 2010; Yoo, 2005; Kiran and Guris, 2009). For instance, this bidirectional causal relationship can be proven by Yoo's (2005) study on the causality between electricity consumption and economic growth in Korea from year 1970 to year 2002. Therefore, increase in electricity consumption in Korea will give a big impact to growth and it will then stimulate further electricity consumption.

Moreover, from Kiran and Guris (2009) and Shahiduzzaman and Alam (2012) investigation by using Granger causality test, the authors found that causality between both variable are bi-directional. This means that, both the growth and energy consumption affect each other at the same time. Since both the variables affect each other, one of the variables will have an important impact to another variable.

According to Ghali and El-Sakka (2004) research in Canada and Dagher and Yacoubian (2012) and Abosedra, Shahbaz and Sbia (2014) in Lebanon, there is bidirectional causality between energy consumption and economic growth in targeted countries. Since energy is a limiting factor to growth, output growth of a country will be negatively affected by supply shock of energy. To avoid the shock of energy supply which can adversely affect the growth, priority must first be given to the development of energy sector.

In addition, a positive bidirectional relationship between the two variables can happen when the increase in energy consumption is caused by the increase in growth and after a certain period, economy growth is boosted by the increased energy consumption. For instance, when there is economic growth with high employment rate, it will increase the energy used hence it will help to boost up growth. This positive relation can be proven by Hamdi and Sbia with their research in Bahrain from year 1980 to year 2008 (Hamdi and Sbia, 2014).

Furthermore, this relationship is also supported by research did by Yang (2000) and Cheng-Lang, Lin and Chang (2010) state that there is bidirectional causal between growth and energy consumption in Taiwan which contradict from the research did by Cheng and Lai (1997). Cheng and Lai found that GDP affected energy consumption in Taiwan but not vice versa.

2.0.4 No Causal Relationship

From all the journals we have found earlier, it shows that economic growth and energy consumption has causal relationship, either it is running in unidirectional direction from growth to energy or from energy to growth or the two variables have bidirectional causality. However, there are also a number of researchers who found that there is inconclusive link between growth and energy. This case happened when the two variables did not affect each other. For instance, when an output growth in a county is increasing or decreasing, energy consumption will not be affected or vice versa.

The reducing energy consumption in India did not affect their output growth due to there is no co-integrated relation between the two variables (Zahid, 2008). Furthermore, Zahid also found the same result in Nepal except for petroleum as there is unidirectional running from petroleum to GDP.

Similarly, this happened in the United States where the United States economic growth has no causal linkage to the energy consumed in that country (Cheng, 1995; Yu and Hwang, 1984). Both the authors made the same conclusion using different technique and time period in testing the causal relationship between the two variables in US which is different from the result found by Kraft and Kraft.

In short, there is still no exact result showing the direction of causality between economic growth and energy consumption as from the results of previous researches, there are mixed results from one study to another. They found different directions of causal relationship, whether it is bi-directional, unidirectional or there is no causality between energy consumption and economic growth. However, the study on the direction of causal relationship is crucial to confirm the relationship between economic growth and energy consumption before implementing policy.

2.1 Relationship between Technology and Economic Growth

To date, many studies have reported that there is positive correlation between technology advancement and economic growth (Jipp, 1963; Hardy, 1980; Moss, 1981; Lichtenberg, 1993; Saunders, Warford and Wellenius, 1994). However, these studies only investigate the relationship between technology improvement and economic growth while the directions of causality have rarely been observed. Therefore for this section, we focus on reviewing the causal relationship between technology development and economic growth. Does the advancement of technology leads to economic growth or the fast-growing economies leads to technology advancement? It is a vital question to be solved because the answer of causality test is important for government to set priorities in the allocation of limited resources to sustain economic growth. Thus, knowing the causal relationship between technology and economic growth is highly needed. Below are the studies that have been done in different countries and period of time.

2.1.1 Impact of Economic Growth towards Technology

Based on the review from previous studies, it is less likely to have only unidirectional causality from economic growth to technology advancement because technology development tends to contribute to economic growth. Except for researches done by Shiu and Lam (2008) where they found out that there is unidirectional causality runs from real GDP to ICT development in less developed countries. ICT development is not found to be an important driver for economic growth in less developed countries because of the under development of other complementary factors such as business environment and education. Another study shows that countries with better economic performance have more technologies which in turn use to enhance their competitive advantage (Avgerou, 2003).

2.1.2 Impact of Technology towards Economic Growth

Technology-led economic growth occurs when technology demonstrates a stimulating influence across the overall economy. However, the effect is not independent from the nation itself. For example, the contribution of Information and Communication Technology (ICT) development to the overall economy has varied among countries, even though many studies find ICT development is one of the factors that affect economic growth (Lee, 2011). In our review, results of the causal relationship from technology development to economic growth have been mixed.

Many researchers hav found evidence in proving that technology has significant impact on economic growth (Duggal et al., 2006; Colecchia and Schreyer, 2002; Piatkowski, 2003). For example, the earliest research was done by Hardy (1980) on the impact of telephone service towards economic development and the result show that telephone does contribute to organizational efficiency and information diffusion which aided economic development. It is also found that ICT capital has contributed positively to economic growth in nine OECD countries despite different positions in the business cycle (Colecchia and Schreyer, 2002). The finding is also supported by Piatkowski (2003) who did his research in Poland and found that ICT investment contributed to output growth as well as labour productivity. Another example is given when Duggal, Saltzman and Klein (2006) and Baily and Lawrence (2001) findings indicate that ICT makes significant contributions to economic growth in the United States. Not only that, the positive causality running from technology to economic growth has been further proven by recent study did by Kumar, Kumar and Patel (2014) research in Small Pacific Island State covering period from 1979 to 2012.

Also, it is found that contribution of technology is country-specified when Jalava and Pohjala (2002) did their studies on advanced economies. They found out that in the United States, the impact of ICT development on productivity growth has not only been limited to the computer and semi-conductor producing industries, but it also took place in industries that uses ICT. In the same journal, however, it is found out that the effect of ICT development is much weaker in other G7 countries.

On the other hand, Lee, Xiang and Kim (2008) findings indicate that the impact of Information Technology (IT) investment on productivity in China is very similar to the United States and concluded that China should invest more in IT which promote economic growth. Similarly, studies of Chou, Chuang and Shau (2014) on 30 OECD countries over the period of 2000 to 2009 found out that IT has positively affected total factor productivity (TFP) and hence production output of an economy through IT-induced externalities and IT-leveraged innovations. This result is consistent with findings by Sener and Saridogan (2011) which states that advances in technology innovation improve the global competitiveness and drive the economic growth in high income OECD countries. Not only that, technology of renewable energy can have large contribution to the economic development and job creation by improving the national energy security and reducing oil dependence (Sawin, 2004).

However, many studies also argue that there is not much evidence to indicate that technology development can significantly contribute to economic growth (Avgerou, 1998; Jorgenson and Motohashi, 2005; Pessoa, 2007). According to Avgerou (1998), the development of ICT is necessary in order for developing countries to participate in the emerging global economic, but it is not sufficient to cause economic growth. Also, in pursuit of continuing economic development, ICT development itself is not adequate to create economic growth without leveraging the human resources (Wang, 1999). Jorgenson and Motohashi (2005) also did their studies on Japan and found out that expansion of investment in IT equipment and software in Japan during the late 1990s is a precise parallel with the United States. However, Japan had encountered a severely depressed economic environment despite economic boom like what happened in the United States because the growth rates of labour input plummeted in Japan during the 1990s, dragging down the economic growth. The similar result showing insignificant relationship between ICT investments and economic growth in Japan has also been supported by recent study done by Ishida (2014). Not only that, Pessoa (2007) uses R&D outlays as proxy for technology innovation and fails to find significant impact of R&D intensity on economic growth in advanced economies.

Besides affecting economic growth directly, technology can also contribute to economic growth through factor of productions such as capital and labour.

2.1.1.1 Indirect Impact through Capital

Technology can contribute to economic growth indirectly through capital input. For example, the study of effects of potential technological improvements in cement industry found that technological shift can improve productivity when less material is used for the same final structure (Habert, Billard, Rossi, Chen and

Roussel, 2010). Another study done by Jorgenson (2001) on the study of information technology in U.S. economy find that the decrease in prices of information technology caused by developments in semiconductor technology has contributed to the enhancement of role of IT investment as a source of economic growth in the country.

2.1.1.2 Indirect Impact through Labour

According to Brown and Campbell (2002), implementation of new technology increase skills and productivity of labour at national level which contribute to economic growth. They suggest that use of new technology changes the way work is done and organisations function and production have become more efficient. In addition, FDI is essential to growth as it has become an important vehicle for transfer of technology which will then enhance economic growth is proven by Borensztein, Gregorio and Lee (1998). However, the author states that this happen only when the beneficial country has a minimum threshold stock of human capital. This implies that human capital do play an important role in use of foreign technology to help in economic growth. The statement is also supported by Kraemer and Dedrick (1999) who state that investment in IT can lead to growth in labour productivity and GDP even when controlling for growth in non-IT investment.

2.1.3 Bidirectional Causal Relationship

On the contrary, there were also number of studies prove that there is bidirectional causality between economic growth and ICT (Madden and Savage, 1997; Shiu and Lam, 2008; Kaur and Malhotra, 2014; Yoo and Kwak, 2004). For example, the results of Madden and Savage (1997) studies in Central and Eastern European (CEE) indicate that there is two way between telecommunications advancement and economic growth and they found evidence of growth preceding investment. Shiu and Lam (2008) also concluded that, there is a bidirectional relationship between real GDP and ICT development for European countries and other high-income group. The result of this study shows that, as country's income level and standard of living increase, it increases the demand for telecommunication services, which in turns, increases investment on telecommunication and national income again. The two-way bidirectional causality is further confirmed by the causality test carried out in Asia by Chakraborty and Nandi (2014). Although Dutta (2001) studies found out the existence of bidirectional causality, the evidence for causality runs from telecommunication technology to economic development is considerably stronger than causality for opposite direction.

In more recent studies, Kaur and Malhotra (2014) found out that ICT development plays an important role in economic development in India and in return, the growth of economic activities that involve the use of ICT are contributing back to the ICT development. Similarly, by using Granger causality test to analyse the causal relationship between telecommunication investment and economic growth in the US economy, Wolde-Rufael (2007) found that there is feedback causality between these two variables. Therefore, with a huge investment in telecommunication sectors, it will help to enhance US growth and at the same time improve telecommunication sector. Also, this positive bidirectional causal relationship can be further proven by Yoo and Kwak (2004) research on causality between economic development and information technology investment in Korea covering period from 1965 to 1998 and research conducted by Shahiduzzaman and Alam (2014) in the case of Australia from year 1965 to 2011.

2.1.4 No Causal Relationship

Similar to unidirectional causality from economic growth to technology advancement, the absence of any causality relationship between the two seldom happen, apart from Kraemer and Dedrick (1993) examination. The result of their examination indicate that there is a strong correlation between IT investment and productivity growth in 11 Asia-Pacific countries but does not provide sufficient evidence of causal relationship because of IT development is relatively small in overall investment picture, and the broad array of factors which affect the economic growth.

To conclude, the results of previous researches in general have been mixed even though they are more towards either bidirectional causality between technology advancement and economic growth or unidirectional causality from the former to latter. Therefore, it is very important for us to examine the causal relationship between the two before implementing policy that generate sustainable economic growth in Malaysia.

2.2 Relationship between Technology and Energy Consumption

Technology breakthroughs play an important role in affecting our standard of living in different ways. For instance, technology innovation that promotes energy efficiency can reduce energy consumption while machineries that substitute labours might consume more energy. With this contradicting impact of technology, together with the rise of awareness on environmental issues, people are now taking into consideration on how technology affect energy consumption because energy sources such as fossil fuels could harm the environment through air pollution and water pollution. This is why it is important to know whether the marginal benefit of implementing an innovative technology is more than the environmental cost before the technology is introduced into the market. Hence, we shall review articles on how technology and energy consumption influence each other.

2.2.1 Impact of Technology towards Energy Consumption

Due to the complexity of relationship between technology and energy consumption, the impact of technology on energy consumption is rather ambiguous and debatable. There are two contradicting points of view on how technology affects energy consumption. We shall further discuss them below.

Quite a number of researchers are convinced that investment in technology might not be as advantageous as it seems as they think that technology will increase the consumption of energy which might not be sufficient to meet future needs (Jorgenson and Fraumeni, 1981; Røpke, Christensen and Jensen, 2010; Tao, 2011). For example, the study of technology's impact on energy consumption found that technological change is energy consuming (Jorgenson and Fraumeni, 1981). It is also found that computers and other related devices increase energy consumption (Røpke, Christensen and Jensen, 2010). Besides, Sadorsky (2012) also found that demand for electricity increases when there is an increase in information and communication technology (ICT) which is measured using internet connections, mobile phone subscriptions or PCs in emerging economies. The finding is also supported by Aebischer and Hilty (2014) who found that overall energy used for ICT is increasing even though energy efficiency of ICT hardware has been significantly improved.

On the contrary, some researchers argue that energy efficiency technology will not only reduce the energy consumption but at the same time improving the country's economic growth by increasing productivity (Romm, 2002; Tang and Tan 2012; Cho, Lee and Kim, 2007). In other words, the advancement of technology will improve energy efficiency. For example, a research done in Malaysia by Tang and Tan (2012) indicate that increases in technology innovation (measured by the number of patents) as well as energy prices contributed to a reduction of energy consumption and thereby making the economic growth more environmental friendly. The finding is also supported by research done by Romm (2002) who found that the Internet does not resulted in an acceleration of electricity demand; instead it appears to be contributing to economic growth. ICT investment in Japan also leads to a fair reduction in energy consumption (Ishida, 2014). However, it will not contribute to an increase in economic growth which happened in other countries. Also, it is found that scaling advanced complementary metal-oxide semiconductor or CMOS will not only improves performance but also reduces power consumption (Borkar, 1999). Next, study done by Berndt, Kolstad and Lee (1993) found that technological change is energy saving.

Furthermore, studies also found that energy consumption will increase as investment in technology increase until threshold level where the energy consumption will start to decline. For example, the result of study done by Shahbaz, Sbia, Hamdi and Rehman, (2014) shows that there is a long run unidirectional causality running from ICT to electricity consumption where an increase in ICT investment will cause electricity consumption to increase and the demand of electricity consumption would start to decline after ICT has developed to a certain point. This is also supported by study done in US where an increment in ICT investment could lead to an increase in energy consumption because the substitution effect is already advanced there and further advancement of technology will have a larger income effect (Takase and Murota, 2004). Energy efficiency is also found in Mexican cement industry which is mainly due to the significant improvements in plant efficiency (Sterner, 1990).

Last but not least, there are also researchers who ended up in having mix result from their study. For example, a study focusing on manufacturing sectors of Ontario, Canada using energy information from 1962 to 1984 found that technologies used is oil-saving but natural gas-using which could be explained by the low prices of natural gas (Mountain, Stipdonk and Warren, 1989).

2.2.2 Bidirectional Causal Relationship

Nevertheless, some researchers have different opinion from the result we discussed above. They argue that both variables could Granger cause each other which means there is a bi-directional relationship between technology and energy consumption. In other words, an increase in energy consumption would encourage the innovation of energy efficient technology which will then result in a reduction of energy consumption (Sawin, 2004; Elimelech and Philip, 2011; González-Gil, Palacin, Batty and Powell, 2014). For example, transportation sector has become one of the most energy-consuming and polluting sector regardless the country is in developed or developing status; thus a combination of strategies as well as regenerative braking technology is introduced to optimise energy used (González-Gil, Palacin, and Powell, 2014).

Another obvious example is given in a study done by Zaman, Khan, Ahmad and Rustam, (2012) in Pakistan to investigate the causal relationship between energy consumption and several agricultural technological factors. They found that there is a bi-directional causality relationship between one of the agricultural technology factors (number of tractors) and energy consumption. Janulis (2004) strengthen the statement when she found that energy consumption is reduced by introducing seed preservation technologies instead of the implementation of usual seed drying which consume more energy.

It is also found that distillation, the most popular separation technology used in chemical process industry which has high energy consumption is reduced through innovation of energy efficient distillation technologies (Kiss, Landaeta and Ferreira, 2012). Nevertheless, a review is done on potential reductions in energy consumption from the implementation of state-of-the-art seawater desalination technologies after it is found that seawater desalination is still more energy consuming compared to the use of conservative technologies for the treatment of freshwater despite major advancement in desalination technology (Elimelech and Philip, 2011).

Moreover, a study shows that the portion of energy consumed by heating, ventilation and air-conditioning (HVAC) exceed half of the total energy consumed in a building and this triggers the innovation of energy efficient cooling technology that could potentially reduce energy utilization for cooling (Chua, Chou, Yang and Yan, 2012). The bidirectional causality is also supported by a study that evaluates the energy consumption (production of hot water, heating, cooling, ventilation and lightning) of a traditional massive building in Catania city and found that the consumption is high due to the low efficiency of heating system. Thus, the authors suggest that both building envelope and efficiency of heating plant has to be upgraded to improve energy efficiency of heating systems to allow significant reduction in energy consumption (Gagliano, Nocera, Patania, Detomaso and Sapienza, 2014).

Furthermore, high energy consumption in computer system design has inspired the invention of JETTY to significantly reduce energy consumed by snoop requests in snoopy bus-based symmetric multiprocessor system (Moshovos, Memik, Falsafi and Choudhary, 2001). Another study on energy consumption of telecommunication network found that home networks consume largest part of energy but it could be reduce with the help of new technologies (Lange, Kosiankowski, Weidmann and Gladisch, 2011). The same result is found in the study done by Fettweis and Zimmermann (2008). The authors found that there is a need for new tools, technologies and insights to increase energy efficiency of information and communication technology (ICT) systems due to rising of ICT systems energy consumption. Nonetheless, a study shows that telecommunication sector is responsible for more or less 4% of the global electricity consumption and therefore, the authors introduce current green technologies to promote energy efficiency in ICT (Koutitas and Demestichas, 2010).

In a nutshell, the results of previous studies show the existence of bidirectional causality between technology advancement and energy consumption and unidirectional causality running from former to latter. Therefore, it is important to be clear about the direction of causality before the implementation of technology. Otherwise, we can only improve our standard of living at the expense of inefficient energy consumption.

2.3 Chapter Summary

After reviewing these past researches, inconclusive results are obtained from the studies of the relationships among the variables. The results are especially ambiguous for the studies of relationship between economic growth and energy consumption as some journals we found conclude that there is bidirectional causality, and some says that there is unidirectional causality while some others conclude that there is no causality between the two variables. As for the studies of relationship between technology and economic growth, results obtained are more towards bidirectional causality between technology advancement and economic growth or unidirectional causality from the former to latter. Last but not least, more results show that there is a unidirectional causality running from technology to energy consumption as well as bidirectional causality between them. Therefore, in order to study the linkages between these variables to come out with an exact conclusion on the relationship, we have constructed a model based on Cobb-Douglas Production by adding in energy consumption and technology which will further explain in Chapter 3.

CHAPTER 3: METHODOLOGY

3.0 Introduction of Methodology

In chapter 3, we are going to introduce the econometric model and framework we used to estimate relationship between our data. Our models are built based on theoretical framework which will be discussed further later. In the first model, we are going to study the short run and long run relationship between Malaysian economic growth (dependent variable) and three independent variables which are capital, labour and energy consumption in Malaysia. Next, in the second model, we incorporate technological factor into the equation to study the relationship between the variables in the new model. We have obtained proxies for all of our data ranging from year 1985 to 2012 which give us a total of 28 years of full data.

As for our econometrics methods employed, we apply the concept of cointegration originated by Granger (1981), improvised by Ganger and Weiss (1983) and extended and by Eagle and Granger (1987). The ideology behind cointegration is to explain the long run equilibrium relationship among time series variables. Cointegration analysis is inherently multivariate, as a single time series cannot be cointegrated (Hendry and Juselius, 2000). Thus, our regression models are multivariate in nature as to study effect of various independent variables on dependent variable. To examine our models, we use the Auto Regressive Distributed Lag (ARDL) approach which also called the bound testing method.

After testing long run relationship between the variables, we further employ Granger causality test to study the short run causal relationship between those variables. Two separate unit root tests, Augmented Dickey Fuller (ADF) test and Phillips-Perron (PP) test, are deployed to test the stationarity of our data before cointegration tests are carried out. Stationarity tests are needed to ensure that our series of data meet the requirement of same order of integration with I (d) and linear combination of all variables must be I (d-b).

3.1 Theoretical Model

3.1.1 Cobb-Douglas Production Function

In 1928, Charles Cobb and Paul Douglas published a study which they modelled a simplified view of economy in which they attempt to explain the production output by analysing at the amount of labour involved and the amount of capital invested. In other words, an increase in output in an economy can be explained by either an increase in labour or capital stock. However, the mainstream theory of economic growth only pays attention to the role of labour and capital stock and pay less attention to other variables (Stern, 2004). They usually think of labour and capital stock as primary factor of production as the prices paid for all different inputs are eventually being paid to the owners of primary inputs for the services provided directly or embodied in the produced intermediate inputs. Despite the conventional neoclassical production models that consider labour and capital stock as the only inputs for production, energy economists have increasingly emphasized the crucial role of energy as a production factor for output (Ishida, 2014). Not only that, technology has also become a favourite explanatory variable in growth models after knowing the importance of technology to promote or sustain economic growth (Pianta, 1995).

Therefore, we propose a model with a framework based on Cobb-Douglas production function where we reinforced the production function by adding energy consumption in Model 1 and later both energy consumption and technology innovation in Model 2 to re-investigate the energy-growth nexus in Malaysia after accommodating technology innovation as new control variable. Energy consumption in Model 1 and technology innovation in Model 2 are with the inclusion of its externality impact on economic growth. The reason we applied Cobb-Douglas production function is because it is easy to analyse and it appears to be a good approximation to actual productions as it takes diminishing marginal returns of factor of production into account (Yuan, Liu and Wu, 2009). The function can be stated as follow:

3.1.1.1 Energy Consumption

Model 1: $\mathbf{Y_t = f\ (A, K_t, L_t, E_{1t})}$

(1)

$$\mathbf{Y_t = AK_t^{\beta 1} L_t^{\beta 2} E_{1t}\, \varepsilon_t}$$

(2)

where Y is real output; K is capital stock; L is labour force; and E_{1t} reflects the externality generated by the presence of energy consumption; and A represents the economic environments.

In many recent studies, energy economists have started to take in energy as a factor of production and study its relationship with economic growth. For example, Stern (2000), Soytas and Sairi (2002) and Ghali and El-Sakka (2003) have incorporated energy use as an additional variable to labour and capital stock in the production function. Ecological economists often ascribe energy to the central role in economic growth (Stern, 2010). But theories that try to explain growth entirely as a function of energy supply, while ignoring the roles of other variables, are also incomplete. The first law of thermodynamics, which is the conservation law, emphasizes on mass-balance principle which means in order to obtain a given output, equal or greater quantities of matter must be used as inputs (Ayres and Kneese, 1969). In other words, there are minimal input requirements for any production that produces outputs. While the second law of thermodynamics, also known as the efficiency law, implies that a least amount of energy is essential to carry out the transformation of matter. Thus, all production includes the movement or transformation of matter in some ways that require energy. In short, we have to take energy as our additional variable in our production function without ignoring other inputs.

The on-going debates among energy economists on the relationship between energy consumption and economic growth have led to the emergence of different views as discussed in our literature review. Despite different views, there are four different hypotheses for energy- growth nexus (Squalli, 2006). First of all, the growth hypothesis treats energy as a factor of production for output and theoretically, it implies that the economy is energy dependent. This hypothesis is supported by Asghar and Rahat (2011), who suggest that energy is the prime source of value in production and manufacturing of all goods because other factor of production like labour and capital stock cannot do without energy. According to this hypothesis, energy use is a limiting factor to economic growth. Thus, implementation of policy to reduce energy use or reduction in energy supply will adversely impact the economic growth. On the contrary, the conservation hypothesis states that there is long-term relationship running from economic growth to energy use but not the other way round. This implies that even severe energy crisis will not retard the economic growth. Next, the neutrality hypothesis treats energy use as an insignificant part of economic output and thus no causality between these variables. The main reason for the neutral impact of energy use on economic growth is that the cost of energy is very small as a proportion of total GDP hence it is not likely to have significant impact on economic growth (Ghali and El-Sakka, 2003). It also been argued that the impact of energy consumption on growth is subject to the stage of economic growth and the structure of economy of the country concerned (Cheng, 1995). As an economy grows, its output is likely to shift towards services sector, which are not as energy-intensive as compare to industrial activities. Lastly, feedback hypothesis assumes there is bi-directional relationship between energy consumption and economic growth. This implies an increase in economic growth will stimulate energy consumption, and contrariwise, an increase in energy use will accelerate economic growth.

On the basis of previous studies, such as those by Zeshan and Ahmed (2013) and Arnim and Rada (2010), the impact of energy consumption on economic growth can be indirect through capital and labour. In other words, the externality of energy consumption on economic growth is also dependent on capital and labour. Hence, we assume that E_{1t} is a function of capital (K), labour (L) and energy consumption (EC), which can be written as follows:

$$\mathbf{E_{1t} = f\,(K,L,EC^{\varphi})^{\theta}} \tag{3}$$

Substitute equation 3 into equation 2, we obtain:

$$\mathbf{Y_t = AK_t^{\beta 1}L_t^{\beta 2}\,(K^{\theta}L^{\theta}EC^{\varphi\theta})}$$

$$\mathbf{= AK_t^{\beta 1+\theta}L_t^{\beta 2+\theta}EC^{\varphi\theta}\,\varepsilon_t} \tag{4}$$

Taking the natural log-linear form of equation 4, we obtain the following equations for Model 1:

Model 1: $\ln Y_t = \ln A + (\beta_1+\theta)\ln K_t + (\beta_2+\theta)\ln L_t + \varphi\theta EC + \varepsilon_t$

(5)

where $(\beta_1+\theta)$, $(\beta_2+\theta)$ and $\varphi\theta$ are the output elasticity of capital, labour and energy consumption respectively. Equation 5 indicates that if $\theta>0$, the presence of energy consumption will augment the elasticity of output with respect to capital and labour.

3.1.1.2 Technology Innovation

Model 2: $Y_t = f(A, K_t, L_t, EC_t, E_{2t})$

(6)

$$Y_t = AK_t^{\beta 1+\theta} L_t^{\beta 2+\theta} EC_t^{\varphi\theta} E_{2t}\,\varepsilon_t$$

(7)

where Y is real output; K is capital stock; L is labour force; EC is energy consumption; E_{2t} reflects the externality generated by the presence of technology innovation; and A represents the economic environments.

Based on neoclassical growth theory, there is no other factor for continuous economic growth besides technological progress. As the level of technological knowledge increases, the functional relationship from input to output changes, either better qualities or more quantities of output can be produced from the same amount of input. However, this theory does not explain how the technology improvement comes about. The neoclassical growth theory just assumed the technological progress to happen exogenously, so the model is said to have exogenous technological change. In our production function, we attempt to endogenise the technological change by adding technology variable in order to explain the technological progress within the growth model and to examine the impact of technological progress to economic growth and energy consumption.

3.1.1.2.1 Technological Innovation and Economic Growth

As emphasized by the neoclassical and endogenous growth theories, technological progress could promotes long-term economic growth (Solow, 1956; Romer, 1990). Despite both theories presented that technological change is the main driver for long-term economic growth, neoclassical theories assume the evolution of technological progress is given exogenously while endogenous growth theories stated that technological change arises, not all but large parts, because of intentional actions taken by people who respond to the market incentives (Romer, 1990). In other words, good market or economic performance could encourage people to innovate in order to gain more from the market. For example, rising economic growth and standard of living have stimulated investment and innovation on telecommunication industry in developed countries due to increasing demand for telecommunications services (Shiu and Lam, 2008).

On the other hand, technology development also contributes to economic growth. The impact of technology advancement and its spillover effects have been a major topic in economic growth. The spillover effects come from the ideas that technology development are non-rival, which implies that they can be embodied in other similar industries without duplicating upfront R&D activities and thus having a spillover effect (Erk, Ates and Tuncer, n.d). In other words, the beneficial effects of new technological knowledge is not necessarily limited to the firm who invented it, but other firms that operate in similar technology areas (Bloom, Schankerman and Reenen, 2010). The direct implication of these spillover effects are that technology advancement is not necessarily subject to diminishing marginal productivity like labour and capital do, nor is the production function limited by constant return to scale (Duggal et al., 2006). According to the test carried out by Bloom et al. (2010), they showed that technology spillover effects did occur in United States. Therefore, technology advancement is crucial in sustaining long-run economic growth because of its spillover effect.

3.1.1.2.2 Technological Innovation and Energy Consumption

From our literature review, we can clearly see that technology advancement can either increase or reduce energy consumption. There are several reasons to explain how technology can lead to significant increase or reduction in energy use. To start, we first see the basic classification of environmental effects of technology advancement (Hilty, 2008). In general, there are three levels of technology impact on the environment. The primary or first-order effect is the effect of the physical existence of technology (environmental impacts of production, use, recycling and disposal of technology hardware). The secondary or second-order effects is the effect of changes in processes resulted from technology advancement, such as changes in production or transportation. The tertiary or third-order effect is the environmental effect of medium or long term adaptation of behaviour and economic structure to the technology advancement. These three orders might have different effects on energy use in an economy.

Therefore, it is necessary to take the all three level of effects into account to determine the impact of technology on energy use.

Technology advancement might reduce energy consumption and thus has positive impact on environment in several ways. Toffel and Horvath (2004) emphasized on the potential energy savings accruing from decreasing the need for business travel through the use of wireless information technologies. Similarly, education and training regarding the environmental management and technology can be achieved in a more efficient way through distance teaching via Internet. Moreover, it is also widely acknowledged that the ICT contributes significantly to dematerialisation in broad industrial sectors through substitution and optimization of material, thus reduces energy consumption (Hilty, 2008). While proven to have substitution and optimization effects on energy consumption, some researchers find technology development leads to more energy consumption. Huber and Mills (1999) have stated that the digital age is very energy-intense and estimate that the energy use for computer and the Internet range from 8% to 13% of total United States electricity consumption. Besides, Forge (2007) also points out the unsustainability of many ICT trends due to large power consumption in data centres. In short, the impact of technology on energy consumption as a whole depends on whether these negative effects offset the associated optimization and substitution effect.

Not only that, the rebound effect of energy-efficiency technologies will change in energy use in an economy. This effect refers to the way that a change in the implicit price of using an energy consuming good or services (Gillingham, Kotchen, Rapson and Wagner, 2013). For example, a new fuel-efficient car reduce the fuel consumption might encourage people to drive more because it is less costly to drive. The indirect rebound effect is the income effect on energy use through demand for other goods and services (Gillingham et al., 2013). For instance, owners of a more energy-efficient vehicle are able to spend less on fuel and may decide to spend the savings on extra flights for vacation. Some analysts also mentioned the embedded energy rebound effect which captures the idea that the energy-efficient products may require more energy to produce (Gillingham et al., 2013). This can be classified in primary or first order of environmental effects on technology advancement as mentioned above. Therefore, whether technology affects energy use positively or negatively is also affected by all the rebound effect.

On the other hand, Jorgenson (2001) and Campbell (2002) found that the technology development can affect economic growth indirectly through capital and labour. Furthermore, Romm (2002) found out that advancement of technology can enhance the energy efficiency and thus stimulate economic growth. These studies suggest that the magnitude of externality of technology on economic growth is dependable on capital stock, labour and energy consumption. Hence, we derive E_{2t} as a function of capital (K), labour (L), energy consumption (EC) and technology innovation (TECH), which can be written as follows:

$$\mathbf{E_{2t} = f\,(K,L,EC,TECH^{\rho})^{\lambda}} \tag{8}$$

Substitute equation 8 into equation 7, we obtain:

$$\begin{aligned}\mathbf{Y_t} &= \mathbf{AK_t^{\beta1+\theta}L_t^{\beta2+\theta}EC_t^{\varphi\theta}\,(K^{\lambda}L^{\lambda}EC^{\lambda}TECH^{\rho\lambda})} \\ &= \mathbf{AK_t^{\beta1+\theta+\lambda}L_t^{\beta2+\theta+\lambda}EC_t^{\varphi\theta+\lambda}TECH^{\rho\lambda}\,\varepsilon_t}\end{aligned} \tag{9}$$

Taking the natural log-linear form of equation 9, we obtain the following equations for Model 2:

Model 2: $$\ln Y_t = \ln A + (\beta_1 + \theta + \lambda)\ln K_t + (\beta_2 + \theta + \lambda)\ln L_t + (\varphi\theta + \lambda)\ln EC + \rho\lambda TECH + \varepsilon_t \quad (10)$$

where $(\beta_1+\lambda)$, $(\beta_2+\lambda)$, $(\beta_3+\lambda)$ and $\rho\lambda$ are the output elasticity of capital, labour, energy consumption and technology innovation respectively. Equation (10) indicates that if $\lambda>0$, the presence of technology innovation will augment the elasticity of output with respect to capital, labour and energy consumption.

3.2 Data Description

3.2.1 Definitions of Variables

Variable	Proxy	Definition by World Bank Development Indicators
GDP	Malaysia's Gross Domestic Production (GDP) per Capita (constant LCU)	"GDP divided by mid-year population. GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. Data are in constant local currency."
K	Malaysia's Gross Capital Formation (% of GDP)	"Consists of outlay on additions to the fixed assets of the economy plus net changes in the level of inventories."
L	Malaysia's School Enrolment, Tertiary (number of students)	"Total enrolment, regardless of age, to the population of the age group that officially corresponds to tertiary level of education. Tertiary education, whether or not to an advanced research qualification, normally requires, as a minimum of admission, the successful completion of education at secondary level."
EC	Malaysia's Energy use (kg of oil equivalent per capita)	"Use of primary energy before transmission to other end-use fuel, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport."
TECH	Malaysia's Research and Development Expenditure	"Current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development."

Source: World Development Indicator

3.2.2 Rationale behind Choosing Our Proxies

3.2.2.1 Gross Domestic Product (GDP)

GDP is an important measurement to determine whether the country is experiencing growth and to provide information of the economy size (Callen, 2012). According to Blanchard and Johnson (2013), GDP is defined as the total value of goods produced and services provided in a country during one year. GDP is an important economic measure because it is able to project a country's health in just one number. Hence, GDP can be considered as a very essential variable that is worth to be studied. There are a lot of macroeconomic factors which will determine the magnitude the figure of GDP, yet we decided to focus our research study on only four independent variables mentioned in the model and investigate the relationship between them.

We have chosen Gross Domestic Production (GDP) per Capita as our proxy for Malaysian economic growth as it has excluded the effect of inflation. Thus, it is more accurate to be used as an indicator as compared to nominal GDP which is not adjusted for inflation.

3.2.2.2 Capital (K) and Labour (L)

As cited in our theoretical model, capital and labour are the two core variables that are found to be the engines of a country's economy. Thus, we include both capital and labour in both of our models as we are using the Cobb-Douglas production function as the foundation of our models. According to

Omri and Kahouli (2013), domestic capital is important in promoting higher economic growth. Besides, capital formation is found to also have indirect impact towards economic growth through encouraging technological advancement (Rahman and Shahbaz, 2011). Thus, better capital accumulation will improve the GDP.

On the other hand, labour is often a topic of discussion much related to the GDP growth rate. Increasing labour force participation is found to have positive effect on a nation's economic growth. According to Bryant, Jacobsen, Bell and Garrett (2004), increased employment in top 5 OECD nations has generated an additional $ 1,215 million of GDP. Moreover, Daly and Regev (2007) also found that labour force increment contributed about 1.7 percentage points per year to the average annual growth in GDP. Based on past studies and conventional economics theories, we are expecting a positive relationship between K and GDP and also L and GDP.

Gross capital formation is the chosen proxy for our capital variable. As defined by World Development Indicator, gross capital formation includes both private and public investment in fixed assets, inventories changes and net acquisition of valuables. In another words, it represents the investment component in GDP. The expenditure side explanation of GDP states that the main components of GDP are consumption, investment, government expenditure and net export. Thus, gross capital formation is considered as an appropriate proxy with substantial influence on GDP. On the other hand, we have chosen the amount of tertiary education student enrolment to be the proxy of our labour variable. This can be explained as it can better reflect the technology variable in our model because higher skilled workers can better operate technologies. Another reason is also because the full data for labour force in Malaysia is not available to us.

3.2.2.3 Energy Consumption (EC) and Technological Factor (TECH)

The key independent variables in our research are energy consumption and technological factor. Their impacts on GDP are widely discussed by economists and researches as mentioned in our literature reviews and theoretical models. The importance of both these variables cannot be overemphasized. Hence, we would like to include energy consumption and technological factor as the two critical explanatory variables in our models. For this, we are expecting a positive relationship between EC and GDP and also TECH and GDP.

Primary energy use is the proxy for our energy consumption variable as secondary energy is converted from primary energy, so primary energy consumption has already taken secondary energy consumption into account. Besides, the process of conversion might result in considerable energy losses and hence using secondary energy as indicator may underestimate the energy used (Can, Sathaye, Price and McNeil, 2010).Meanwhile, research and development expenditure is the proxy we have chosen to represent our technology variable. The main reason is because it is the one proxy that can reflect the total efforts the public and private sectors have put in acquiring new knowledge and technologies.

3.3 Econometric Method

As our research focuses solely on Malaysia, we employ time series method to run our proposed model. Time series analysis is also capable of showing different patterns or components in the dataset which are namely trend component, seasonal component, cyclical component and irregular component. Our research paper serves to study the impact of energy consumption in Malaysia on Malaysian economic growth, impact of technology innovation on Malaysian economic growth and finally the causal relationship between these three variables particularly.

We employ two time series approaches, ARDL Approach (Bound Test) and Granger Causality Test, to test the long run and short run relationship between our variables. These two approaches will be explained right after this.

3.3.1 Bound Test (ARDL Approach)

We have employed the ARDL approach developed by Pesaran and Shin (1995), modified by Pesaran and Pesaran (1997) and upgraded by Pesaran, Shin and Smith (2001). ARDL approach, also known as bound test, is one of the common methods employed by researchers in cointegration testing. Other common approaches include the two-step residual-based procedure developed by Eagle and Granger (1987) and the system-based reduced rank regression approach originated by Johansen (1988).

Compare to both alternative approaches mentioned, the ARDL approach has the upper hand of testing relationship between variables in levels which is applicable irrespective of whether the underlying independent variables are purely I (0), purely I (1) or mutually cointegrated. This enables us to disregard the stationarity of our independent variables and do away with the hectic process of confirming the order of integration of our variables. Its flexibility implies that there are no restrictions of having all variables to have the same order of integration. Besides, it also allows us to consolidate both long run and short run relationship between our variables in a standardised structure. Furthermore, ARDL approach can be easily applied on small sample size without having misleading conclusion in hypothesis testing, unlike the Eagle and Granger's two-step residual-based procedure and Johansen's system-based reduced rank regression approach (Naiya and Manap, 2013). Thus, it is more appropriate to employ ARDL approach compare to the other two approaches with our small sample size of 28 years of observations.

The ARDL test is based on standard Wald Test F-statistic to test the significance of lagged levels of our variables under the analysis in a conditional unrestricted equilibrium correction model (ECM) (Pesaran et al., 2001).

In order to carry out the ARDL approach, we first construct the Vector Auto Regression (VAR) of order p for our two functions:

$$Z_t = \mu + \sum_{i=1}^{p} \beta_i + Z_{t-i} + \varepsilon_t \tag{11}$$

where $Z_t$is the vector of both y_t and x_t, where y_t is the dependent variable (GDP) while x_t (K, L, EC and TECH) is the vector matrix of a set of exogenous variable and "t" is the time variable. After that, we then further develop the VAR (p) into Vector Error Correction Model (VECM) form.

$$\Delta Z_t = \mu + \alpha_t + \lambda Z_t + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-1} + \sum_{i=0}^{p-1} \delta_i \Delta x_{t-i} + \varepsilon_t \tag{12}$$

Where $\Delta = 1 - L$.The long run multiplier matrix λis formed as:

$$\lambda = \begin{pmatrix} \lambda yy \, \lambda yx \\ \lambda xy \, \lambda xx \end{pmatrix}$$

(13)

The crossway components of the matrix are unrestricted which indicates that the chosen series can be either I (0) or I (1). Thus, if $\lambda_{yy} < 0$, then y is I (0). On the other hand, if $\lambda_{yy} = 0$, then y is I (1).

According to Narayan and Narayan (2004), the ARDL approach involves two stages:

(1) Establish long run relationship between variables.
(2) Estimate long run relationship between variables.

In order to study whether or not there is a long run relationship in Model 1, we are needed to employ the unrestricted error correction models (UECM):

$$\Delta X_t = \alpha_0 + \sum_{i=1}^{p=1} \beta_{ix} \Delta X_{t-1} + \sum_{i=0}^{p=2} \emptyset_{ix} \Delta Y_{t-1} + \psi_{1x} X_{t-1} + \psi_{2x} Y_{t-1} + \varepsilon_t$$

(14)

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{p=1} \beta_{im} \Delta Y_{t-1} + \sum_{i=0}^{p=2} \emptyset_{im} \Delta X_{t-1} + \delta_{1x} Y_{t-1} + \delta_{2x} X_{t-1} + \varepsilon_t$$

(15)

Next, Narayan and Narayan (2004) states that to test the existence of long run relationship, F-test should be carried out as it will specify which variable should be normalised when the model consists of long run relationship. The null hypothesis and alternative hypothesis for the respective models are formed as below:

H_0: $\psi_{1x}=\psi_{2x}= 0$ (no long run levels relationship)

H_1: $\psi_{1x}\neq\psi_{2x}\neq 0$ (long run levels relationship exists)

(From equation 14)

H_0: $\delta_{1Y} = \delta_{2Y}= 0$ (no long run levels relationship)

H_1: $\delta_{1Y} \neq \delta_{2Y}\neq 0$ (long run levels relationship exists)

(From equation 15)

This can also be indicated as FX ($\frac{X}{Y}$) for equation 14 and FY ($\frac{Y}{X}$) for equation 15.

Narayan and Narayan (2004) also state that the F-test follows a non-standard distribution which depends on:

(a) whether or not the UECM is with drift,
(b) the number of explanatory variables and
(c) whether or not the variables included in the UECM are of one order of integration I(1) or zero order of integration I(0).

We obtain our critical values developed by Pesaran et al. (2001). After establishing the cointegration, we carried out a two-step procedure in the second stage to estimate the model. We first use Schwarz Information Criteria (SIC), which is a criterion for model selection among a finite set of models, to select the optimal order of the lags in the ARDL model. We then use OLS method to estimate the chosen model. To examine the impact of energy consumption and technology innovation in Malaysia on Malaysian economic growth, we estimate the following UECM of the ARDL model:

$$\Delta lnGDP_t = \beta_0 + \beta_1 lnGDP_{t-1} + \beta_2 lnK_{t-1} + \beta_3 lnL_{t-1} + \beta_4 lnEC_{t-1} + \sum_{i=1}^{p} \beta_5 \Delta lnGDP_{t-i} + \sum_{i=0}^{p} \beta_6 \Delta lnK_{t-i} + \sum_{i=0}^{p} \beta_7 \Delta lnL_{t-i} + \sum_{i=0}^{p} \beta_8 \Delta lnEC_{t-i} + \varepsilon_{1t} \quad (16)$$

$$\Delta lnGDP_t = \beta_{10} + \beta_{11} lnGDP_{t-1} + \beta_{12} lnK_{t-1} + \beta_{13} lnL_{t-1} + \beta_{14} lnEC_{t-1} + \beta_{15} lnTECH_{t-1} + \sum_{i=1}^{p} \beta_{16} \Delta lnGDP_{t-i} + \sum_{i=0}^{p} \beta_{17} \Delta lnK_{t-i} + \sum_{i=0}^{p} \beta_{18} \Delta lnL_{t-i} + \sum_{i=0}^{p} \beta_{19} \Delta lnEC_{t-i} + \sum_{i=0}^{p} \beta_{20} \Delta lnTECH_{t-i} + \varepsilon_{2t} \quad (17)$$

where ln denotes the natural logarithm, while Δ denotes the first difference operator. Whereas GDP represents Gross Domestic Product per capita in constant LCU, K represents gross capital formation in percentage of GDP while L represents numbers of tertiary students' enrolment. EC and TECH represent energy use in kg of oil equivalent per capita and research development expenditure respectively. The respective ε_{1t} and ε_{2t} in equation 6 and 7 are the disturbances for the ARDL model. The null hypotheses to test the long run relationship of the model are $\beta_1=\beta_2=\beta_3=\beta_4=0$ and $\beta_{11}=\beta_{12}=\beta_{13}=\beta_{14}=\beta_{15}=0$ for equation 6 and 7 respectively which specify that there are no long run relationship in both equations. The alternative hypotheses are the opposite of the null hypotheses which indicate that at least one β_i (i=1, 2, 3, 4) and β_j (j=11, 12, 13, 14,

15) is not equal to zero, which mean at least one variable has long run relationship. According to Narayan and Narayan (2004), we might possibly arrive at 3 possible conclusions:

(i) We will conclude that the model consists of long run relationship if we can reject the null hypotheses with the computed Wald Test F-statistic of ARDL bound test is greater than the upper bound critical value.

(ii) On the contrary, we must conclude that there is no cointegration in the model if we fail to reject the null hypotheses with Wald Test F-statistic is lower than the lower bound critical value.

(iii) The last possible outcome is where the results are inconclusive as the value of Wald Test F-statistic is found in between the lower bound and upper bound value.

3.3.2 Granger Causality Test

Introduced by Granger (1969) and modified by Sims (1972), the Granger causality test show the correlation between the current value of one series and the past value of other series; but it does not represent the movement of one variable will cause the movement of another. In other words, Granger causality test shows that one variable causes movement in another variable. Since one of the purposes of our study is to determine the causality among the variables, Granger causality test is performed to identify the short run relationship among them. In our first model, we wish to test whether causality exist between energy consumption and economic growth and the direction of causality. In second model, we want to know whether the direction of causality will change if technological factors have been incorporated; that is to determine the causality among technological factors, energy consumption and economic growth.

Also, by incorporating lagged in the model we can know whether or not the histories of dependent variables can be better predicted using the histories of both dependent and independent variables than it can be predicted using the history of dependent variable alone. For example, if it is stated that independent variable (X) causes dependent variable (Y), it means that X contains useful information for predicting Y over and above the past histories of the other variable in the model. There are three type of causal relationship in the Granger causality:

(i) either the independent variable (X) Granger causes dependent variable (Y), denoted $X \rightarrow Y$; or the dependent variable (Y) Granger causes the independent variable (X), denoted $Y \rightarrow X$,

(ii) bidirectional causal relationship, i.e. Y Granger causes X and X Granger causes Y simultaneously, denoted $X \leftrightarrow Y$,

(iii) and no causal relationship at all.

Before conducting the Granger causality test, the two set of hypotheses which consist of both null hypothesis and alternate hypothesis are stated as follow:

H_0: X does not Granger cause Y

H_1: X does Granger cause Y

and

H_0: Y does not Granger cause X

H_1: Y does Granger cause X

Rejection of null hypothesis can be done when F-statistic is greater than critical valuedeveloped by Fisher and Yates (1963) at 1%, 5% or 10% level of significant. This also indicates that there is a causal relationship between the two variables. There are several possible results we can obtain from Granger causality test (Brooks, 1995):

1. If H_0 in the first set of hypotheses is rejected but not the H_0 of second set of hypotheses, it means that X causes Y and lags of X can be used to predict behaviour of Y, not vice versa. This relationship is denoted by $X \rightarrow Y$ which means that there is a unidirectional causality running from X to Y.
2. If H_0 in the second set of hypotheses is rejected but not the H_0 of first set of hypotheses, it means that Y causes X and lags of Y can be used to predict behaviour of X, not vice versa. This relationship is denoted by $Y \rightarrow X$ which means that there is a unidirectional causality running from Y to X.
3. If H_0 in both set of hypotheses are rejected, it means that X and Y cause each other simultaneously and lags of X can be used to predict behaviour of Y and vice versa. This relationship is denoted by $X \leftrightarrow Y$ which means that there is a bidirectional causality running between X and Y.
4. If H_0 in both set of hypotheses are not rejected, it means that X and Y are independent and lags of one variable cannot be used to predict the behaviour of another.

Also, we must fulfil the assumption of Granger causality test that all variables are stationary before we can proceed to test the causality using the standard F-test of the restriction.

$$\beta_i(1) = \beta_i(2) = \beta_i(3) = ... = \beta_i(p) = 0$$

A variable is said to be endogenous when there is a correlation between the variables and disturbance. And since Granger causality test assumes all variables are endogenous, we do not need to identify whether which variable is endogenous or exogenous whereas the test for exogeneity require that dependent variable is not affected by the error term of independent variable if it is to be exogenous. Furthermore, Granger causality test concerns only the impact of past event of independent variables on the current event of dependent variable and therefore it determines whether or not future value of dependent variable can be forecasted by the current and previous value of independent variables.

There are two models in our research paper whereby the first equation will study the effect of energy consumption, labour and capital on economic growth in Malaysia and the second equation is formed by incorporating technological factors as an independent variable into the first equation. Hence, we will estimate the hypothesis by forming the first equation with GDP as Y_1 and the other independent variables are labelled as K, L, and EC. The second equation will also be formed with GDP asY_2, but the independent variables are K, L, EC and TECH. The ε_t and $\mu_t$are uncorrelated error terms with white noise.

$$\Delta X_t = \theta_0 + \sum_{i=1}^{n} \alpha_i X_{t-i} + \sum_{j=1}^{n} \beta_j Y_{t-j} + \varepsilon_t$$

(18)

$$\Delta Y_t = \gamma_0 + \sum_{i=1}^{m} \lambda_i Y_{t-i} + \sum_{j=1}^{m} \delta_j X_{t-j} + \mu_t$$

(19)

The equation 8represents that changes in variable X is determined by lagged variable X and Y whereas the equation 19 represents that changes in variable Y is determined by lagged variable X and Y. Bidirectional Granger causality happen when lagged Y influence X in equation 18 and lagged X influence Y in equation 19. The null hypothesis and alternate hypothesis are stated as follow:

H_0: $\Sigma\beta_j = 0$ (Lags of Y do not belong to the regression)

H_1: $\Sigma\beta_j \neq 0$(Lags of Y do belong to the regression)

After all the assumptions are fulfilled, we regress X on all lagged X terms and other variables without including any lagged Y variables, the restricted residual sum of square (RSS_R) is computed in EViews. Then, we use F-test to perform hypothesis testing using the formula below:

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

where RSS_{UR} indicates the unrestricted sum of squared residual; RSS_R represents restricted sum of squared residual; m is the number of lags; n represent sample size and k represents the number of coefficient involved in the unrestricted regression.

The decision to reject null hypothesis of Y does not causes X can be made when F-statistic computed using the formula above is greater than the critical value at 1%, 5% or 10% level of significant, otherwise we should not reject it. If null hypothesis is rejected, we can say that lagged Y does belong to the regression which means Y causes X. Then the similar process is repeated by including lagged X terms so that we can clearly see the causality between the variables.

The following equation, Equation 20, 21, 22, 23 and 24 are models formed when we substitute the studied variables into the general equations (Equation 18 and 19). The similar process will be carried out to conduct the Granger causality test.

$$\Delta\, ln\, GDP_t \;=\; \gamma_1 + \sum_{i=1}^{m} \lambda_{1i} \Delta GDP_{t-i} + \sum_{j=1}^{m} \delta_{1j} \Delta K_{t-j} \;+\; \sum_{j=1}^{m} \theta_{1j} \Delta L_{t-j} \;+\; \sum_{j=1}^{m} \varphi_{1j} \Delta EC_{t-j} \;+\; \sum_{j=1}^{m} \omega_{1j} \Delta TECH_{t-j} \;+\; \mu_{1t} \tag{20}$$

$$\Delta\, ln\, K_t \;=\; \gamma_2 + \sum_{i=1}^{m} \delta_{2j} \Delta K_{t-i} + \sum_{j=1}^{m} \lambda_{2i} \Delta GDP_{t-j} \;+\; \sum_{j=1}^{m} \theta_{2j} \Delta L_{t-j} \;+\; \sum_{j=1}^{m} \varphi_{2j} \Delta EC_{t-j} \;+\; \sum_{j=1}^{m} \omega_{2j} \Delta TECH_{t-j} \;+\; \mu_{2t} \tag{21}$$

$$\Delta\, ln\, L_t \;=\; \gamma_3 + \sum_{i=1}^{m} \theta_{3j} \Delta L_{t-i} + \sum_{j=1}^{m} \lambda_{3i} \Delta GDP_{t-j} + \sum_{j=1}^{m} \delta_{3j} \Delta K_{t-j} + \sum_{j=1}^{m} \varphi_{3j} \Delta EC_{t-j} + \sum_{j=1}^{m} \omega_{3j} \Delta TECH_{t-j} + \mu_{3t} \tag{22}$$

$$\Delta\, ln\, EC_t \;=\; \gamma_4 + \sum_{i=1}^{m} \varphi_{4j} \Delta EC_{t-i} + \sum_{j=1}^{m} \lambda_{4i} \Delta GDP_{t-j} + \sum_{j=1}^{m} \delta_{4j} \Delta K_{t-j} + \sum_{j=1}^{m} \theta_{4j} \Delta L_{t-j} + \sum_{j=1}^{m} \omega_{4j} \Delta TECH_{t-j} + \mu_{1t} \tag{23}$$

$$\Delta\, ln\, TECH_t = \gamma_5 + \sum_{i=1}^{m} \omega_{5j} \Delta TECH_{t-i} + \sum_{j=1}^{m} \lambda_{5i} \Delta GDP_{t-j} + \sum_{j=1}^{m} \delta_{5j} \Delta K_{t-j} + \sum_{j=1}^{m} \theta_{5j} \Delta L_{t-j} + \sum_{j=1}^{m} \varphi_{5j} \Delta EC_{t-j} + \mu_{5t} \qquad (24)$$

where ln and Δ denote natural logarithm and first difference operator respectively. Whereas GDP is Gross Domestic Product per capita (constant LCU), K is gross capital formation (percentage of GDP) while L is tertiary school enrolment (number of students), EC is energy use (kg of oil equivalent per capita) and TECH is research development expenditure.

3.4 Chapter Summary

In short, we have built our two models based on Cobb-Douglas production function. Thorough compilations of previous theoretical models are done to make sure we have a solid foundation for our models. We have also chosen our proxies for the independent variables for justifiable reasons as stated above. We ran across various online database sources to ensure we have the best dataset available for our variables which include 28 annual time series data. Next, we are going to employ ARDL approach and Granger causality test to test the long run and short run relationships between all the variables respectively. The results of our tests will be shown and explained in the next chapter.

CHAPTER 4: RESULT AND INTERPRETATION

4.0 Introduction

In this chapter, we focus on interpreting the estimated results we obtained from conducting empirical analysis by employing the methods and tests discussed in Chapter 3. First and foremost, the level of stationary of variables is determined using unit root tests such as Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP). The decision to reject null hypothesis of a unit root [I (1)] is made when the t-statistic is less than critical values that were tabulated by MacKinnon (1991). The rejection of null hypothesis also indicates that the series is stationary. To avoid autocorrelation problem and enhance the reliability of our results, the optimal number of lag lengths were determined based on Schwarz Information Criteria (for ADF test) and Newey-West Bandwidth using Bartlett kernel spectral estimation method (for PP test).

The results of unit root tests are shown in Table 4.1. Then, Table 4.2, 4.3, 4.4, 4.5 report the results of ARDL approach which was employed to determine the long run relationship for both empirical models. They are followed by Table 4.6 and 4.7 which show the results of Granger causality tests that illustrate the short run dynamic linkages between the variables.

4.1 Unit Root Test

As mentioned, Table 4.1 reported the result of both Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test at level and first difference form by taking into account both the case of constant with trend and constant without trend. For the chosen unit root tests employed, the null hypothesis and alternate hypothesis are as follow:

H_0: Series is non-stationary (has unit root)

H_1: Series is stationary (has no unit root)

The optimal number of lag lengths is chosen based on Schwarz Information Criteria (for ADF test) and Newey-West Bandwidth using Bartlett kernel spectral estimation method (for PP test) to avoid autocorrelation problem and boost the dependability of the results we obtained.

According to the result we obtained in Table 4.1, the t-statistics of all variables for ADF test at level form (constant with trend) are statistically insignificant to reject the null hypothesis of non-stationary or a unit root at 10%, 5% and 1% significance level. The failure to reject null hypothesis means that the series has one or more unit root and therefore we proceed to the first difference form. In the first difference form (constant without trend), the t-statistics of all variables for ADF test is less than critical values and hence the null hypothesis of two unit roots should be rejected and we can conclude that the series have only one unit root or integrated of order one [I (1)]. And since the stationary of all variables have been achieved in first difference, we do not need to proceed to the second difference form.

Then, we conducted PP test to complement the results we obtained in ADF test. PP test is perhaps the most common used alternative to the ADF test since it assumes that there is no functional form for the error process of the variables (Mahadeva and Robinson, 2004). In other words, PP test is a 'non-parametric' test. Aside from correcting any serial correlation problem, PP test are also robust to general forms of heteroskedasticity in disturbance. Furthermore, we do not need to specify a lag length for the test regression when we conduct PP test. Most importantly, since our sample size is small, PP test is conducted to overcome the problem of small sample size (Phillips-Perron, 1988). As expected, the result we obtained from PP test is similar to the result of ADF test. We do not reject the null hypothesis of non-stationary or a unit root at 10%, 5% and 1% significant level but we reject the null hypothesis in first difference form.

After conducting both tests, we can conclude that all variables achieved stationary in first difference but not at level form. This also means that all series have only one unit root or integrated of order one [I (1)].

Table 4.1: Results of the Unit Root Tests				
	ADF Test		PP Test	
Variable	Level	First Difference	Level	First Difference
	Constant with Trend	Constant Without Trend	Constant with Trend	Constant Without Trend
Data Period (1985-2012)				
GDP	-1.4122 (0)	-4.6679 (0) ***	-1.4854 (1)	-4.6630 (2) ***
K	-1.8114 (0)	-4.6599 (0) ***	-1.8114 (0)	-4.6600 (0) ***
L	-2.1178 (0)	-5.2226 (0) ***	-2.1178 (0)	-5.2336 (2) ***
EC	-1.3548 (0)	-4.9733 (0) ***	-1.0208 (4)	-4.9860 (4) ***
TECH	-0.1425 (0)	-4.1841 (0) ***	-0.0830 (1)	-4.1841 (0) ***

Note: The null hypotheses for both Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests are that the series is non-stationary or contains a unit root whereas the alternate hypotheses for both tests are that the series is stationary or does not contain a unit root. The rejection of null hypotheses for both tests is based on critical values tabulated by MacKinnon (1991) and it indicates that the series is stationary.

Figures in parentheses ( ) refer to the optimal lag lengths which were determined based on Schwarz Information Criteria (for ADF test) and Newey-West Bandwidth using Bartlett kernel spectral estimation method (for PP test) in order to avoid autocorrelation problem.

*, ** and **** implies that the rejection of the null hypothesis of non-stationary at 10%, 5% and 1% significance level respectively.

4.2 Bound Test (ARDL approach)

After the stationary status for all variables have been investigated by using the ADF and PP test, we moved forward to the ARDL models for the estimation of long run relationship between energy consumption, technology and economic growth.

Due to our small sample size (28 observations) as the data period in our study ranges from 1985 to 2012, we decided to use bound testing procedure to test the long run relationship among the variables. This approach allows us to test the existence of a relationship between variables in levels which is applicable irrespective of whether the underlying regressors are purely I(0), purely I(1) or mutually integrated (Pesaran, Shin and Smith, 2001). Hence, we do not ascertain the order of integration of interested variables by using this ARDL approach. Besides, we examined the model by using the General to Specific approach in choosing the optimal lag length in order to get the closest fitted specification. In order to obtain the optimal lag length, we eliminated those variables which are insignificant except for the level form variables and intercept.

From the testing procedure, the asymptotic distribution of F-statistic is non-standard under the null hypothesis that there is no cointegration relationship between the included variables. In both Table 4.2 and 4.3, GDP in first difference form is measured as the dependent variable and the remaining variables such as capital (K), labour (L), energy consumption (EC) [Table 4.2] and technological factor (TECH) [Table 4.4] are measured as explanatory variables in our model. Later, the results of bound cointegration test are shown in Table 4.3 and Table 4.5 for Model 1 and 2 respectively which have the null hypothesis of the model is $\beta_1 = \beta_2 \ldots \beta_i = 0$ while the alternative hypothesis stated that $\beta_1 \neq \beta_2 \ldots \beta_i \neq 0$.

Subsequently, in order to get valid and robust result, we used several diagnostic checking tests which are Breush- Godfrey Serial Correlation LM test (test for Autocorrelation problem), ARCH test (test for Heteroskedasticity problem), Jarque- Bera normality test (test for normality of model) and Ramsey RESET specification test (test for model misspecification).

4.2.1 The Impact of Energy Consumption on Economic Growth (Model 1)

Based on Table 4.3, the computed F- statistic (Wald Test) for Model 1 is 5.9440 which is greater than the upper bound value (5.61) of 1% significance level. Hence, we can reject the null hypothesis and conclude that capital, labour and energy consumption have a long run relationship with country's economic growth. Based on panel 1(a) from Table 4.2, the high adjusted R-squared (0.8082) indicates the estimated Model 1 has high goodness of fit.

From the ARDL estimation for our Model 1 which consists of K, L, EC and GDP, we obtained consistent result with our expectation which is in line with the previous research. For capital, the estimated result on its relationship and GDP is compatible with pervious research as K positively affects the country's economic growth (positive coefficient of 0.4270) and it is statistically significant at 1% significance level. This is strongly supported by the Solow growth model which explains the country's economic growth by looking at capital accumulation and other factors (Acemoglu, 2011). Not only that, L is also positively affecting economic growth variable, which could also be explained by the same Solow model (positive coefficient of 0.1094) and it is significant at 5% significance level.

The result for relationship between EC and GDP is line with our expectation as well. The estimated results showed that EC positively affects economic growth and it is significant at 10% significance level. This highly wanted result is being supported by most of the previous researched who studied on the impact of EC towards GDP (Shiu and Lam, 2004; Moromito and Hope, 2014; Altinay and Karagol, 2005; Yuan et al., 2007; Shengfeng, Sheng, Tianxing and Xuelli, 2012; Zahid, 2008). These research studies mentioned above obtained similar and consistent results with our studies, which shows the general or natural effect of EC towards a country's economic growth, although the targeted countries are different.

Over and above that, in the context of Malaysia, its energy industry is found to have significant contribution to the economic growth which makes up almost 20 per cent of total gross domestic product. In short, we are able to examine and obtain a more robust result on the relationship between EC and GDP which is in conformity to our purpose of constructing this model. Not only that, our result is in line with the case study done by Zahid (2008) in the context of Pakistan, Bangladesh and Nepal as our nation depends heavily on gas and petroleum too.

Also, through a series of diagnostic checking in panel 1(b) from the same table, it is shown that the underlying variables in the estimated Model 1 are valid and dependable. Under the Breusch-Godfrey Serial Correlation LM test, the probability (p-value) of F-statistic from lagged one (0.4067) and lagged two (0.5783) are greater than all three significance levels (10%, 5% and 1%). For that reason, the null hypothesis of no autocorrelation has not been rejected and we can conclude from here that there is no autocorrelation problem in the estimated Model 1. Under the ARCH test, the p-value for both lagged one (0.7771) and lagged two (0.7874) are greater than all three significance levels (10%, 5% and 1%). Therefore, the null hypothesis of no heteroskedasticity has not been rejected and we concluded that there is no existence of heteroskedasticity problem.

For the normality checking, the p-value (0.5093) is greater than all 10%, 5% and 1% significance levels under the Jarque-Bera normality test. Hence, we do not reject the null hypothesis and concluded that the error term in the Model 1 is normally distributed. Next, under the Ramsey's misspecification test, the p-value (0.2597) is greater than 10% significance level by using eight fitted terms. We, therefore, did not reject the null hypothesis of correctly specified model and concluded that the model is correctly specified at all the three significance level (10%, 5% and 1%). In addition, we test for stability of the coefficients in the estimated Model 1 by using cumulative sum (CUSUM) stability tests. The results (in Appendix) show that the estimated parameters for Model 1 appear to be stable throughout our chosen sample period.

Table 4.2: The estimated ARDL Model Based on Model 1

Panel 1(a)

Variable	Coefficient	T- statistics	Probability
K	0.4270	3.3757	0.0071 ***
L	0.1094	2.2719	0.0464 **
EC	0.6884	1.8702	0.0910 *
C	2.1058	1.8816	0.0893 *
Adjusted R-squared	0.8082		
Standard Error of Regression	0.0174		
F-statistic	9.0466		
Probability (F-statistic)	0.0008		

Panel 1(b)

Diagnostic Checking

i) Autocorrelation (Breusch-Godfrey Serial Correlation LM test)

F(1) = 0.7577 [0.4067] F(2) = 0.5870 [0.5783]

ii) ARCH Test

F(1) = 0.0825 [0.7771] F(2) = 0.2424 [0.7874]

iii) Jarque- Bera Normality Test:

χ^2 (2) = 1.3494 [0.5093]

iv) Ramsey RESET Specification Test:

F-statistic= 3.2015 [0.2597]

Note 1: *, ** and *** indicate variables are significant at 10, 5 and 1 per cent significance level. Figures in squared parentheses [ ] refer to marginal significance level (p-value). All variables tested are in natural log form.

Table 4.3: Bound Test Based on Model 1		
Computed F-statistic: 5.9440 ***		
Null hypothesis (H_0) : No Cointegration		
Decision Rule: Reject H_0 if computed F-statistic value greater than upper bound value. Otherwise, do not reject H_0.		
	Critical Value	
	Lower	Upper
1% significance level	4.29	5.61
5% significance level	3.23	4.35
10% significance level	2.72	3.77
Conclusion: Reject H_0 at 1% significance level.		
Note: The critical value taken from Pesaran et al. (2001), Table CI (iii): Unrestricted intercept and no trend.		
*, ** and *** indicate the model is significant at 10, 5 and 1 per cent significance level.		

4.2.2 The Impact of Technology on Economic Growth (Model 2)

For Model 2, we injected additional variable (Technology) into our research model in order to study the overall effect of the role of technology and energy consumption level in promoting economy growth. The following table (Table 4.4) denoted the estimated ARDL model after adding in technological factor. It has become an important issue for us to study Model 2 for the long run relationship among the variables as previous studies found that technology might have an impact on utilizing the energy consumption level and it might bring us different result towards country's economic growth.

Based on Table 4.5, the computed F- statistic (Wald Test) for Model 2 is 6.4751 which is greater than the upper bound value (5.06) of 1% significance level. Hence, we are able to reject the null hypothesis and conclude that capital, labour, energy consumption and technology have a long run relationship with country's economic growth. Based on panel 2(a) from Table 4.4, the very high adjusted R-squared (0.9198) indicates the estimated Model 2'has high goodness of fit.

The difference between Model 2 with the previous Model 1 is we included technological factor into the ARDL estimation. In Model 2, we are going to prove whether or not the advancement of technology leads to economic growth. As expected, the estimated results indicate that TECH positively affects Malaysia's economic growth and the long run relationship is statically significant at 1% significance level. In other words, our result is in tune with the previous studies (Duggal et al., 2006; Colecchia and Schreyer, 2002; Piatkowski, 2003). By the same token, there are researchers who support the above theory through different investigation fields of technology which includes ICT capital investment, ICT development on productivity, technology of renewable energy and other technology-related factors (Colecchia and Schreyer, 2002; Piatkowski, 2003; Duggal, Saltzman and Klein, 2006; Jalava and Pohjala, 2002; Lee, Xiang and Kim, 2008; Sawin, 2004). By referring to the findings of Lee, Xiang and Kim (2008), China's productivity is highly impacted by the information technology (IT) investment and this is exactly what our nation is working on by attracting in IT investment gradually in order to achieve a high skilled oriented country. In addition, the key factor to improve global competitiveness and to achieve high income status (Advancement in Technology Innovation) discussed by Sener and Saridogan (2011) brought the same idea in the context of Malaysia. In Malaysia, technology and innovation is one of the top performing sectors and it grows by double digits percentage-wise since 2012 and affects the country economic status significantly. In short, although different researches support the TECH-led growth hypothesis through different mechanisms, in the end, the natural effect of TECH on GDP is the same. Accordingly, we could understand the role of technology as a key and main driver in structuring a favourable condition for the Malaysian economy.

As we discussed earlier, energy efficiency is dependent on technological advancement which makes technological changes to have an effect on economic growth directly and indirectly. After TECH added into the Model 2, it is crucial for EC to retain its positive sign on its effect towards GDP and it is still significant at 10% significance level. By having an advance level of technology development for the country, EC is still acting as a catalyst in promoting economic growth. However, the coefficient of EC dropped significantly from 0.6884 to 0.2608 after TECH added into the model. This could be reasonably justified that the presence of technology will augment the elasticity of economic growth with respect to energy consumption by a factor of λ as mentioned in our theoretical model.

Not to forget, the K and L are still contributing positive impacts towards the GDP in Model 2 with a slight drop in significance level. This is reasonable to make an assumption that with the stand in of technology, K and L could be reduced in quantity in promoting economic growth in a more effective and efficient way and this could be partially proven by the presence of technology augmenting the elasticity of economic growth with respect of capital and labour. By comparing the coefficient of both capital (K) and labour (L) before and after adding in technological factor, it shows a reduction in value from 0.4270 to 0.2525 and 0.1094 to 0.0219 respectively.

Also, through a series of diagnostic checking in panel 2(b) from the same table, it is shown that the discussed variables in the estimated Model 1 are valid and dependable. Under the Breusch-Godfrey Serial Correlation LM test, the probability (p-value) of F-statistic for both lagged one (0.6955) and lagged two (0.9302 are greater than all three significance levels (10%, 5% and 1%). For that reason, the null hypothesis of no autocorrelation problem has not been rejected and we can conclude that autocorrelation problem does not exist in the estimated model 2. Under the ARCH test, the p-value for lagged one (0.3806) and lagged two (0.4173) are greater than all three significance levels (10%, 5% and 1%). Therefore, we do not reject the null hypothesis of no heteroskedasticity problem and concluded that there is no existence of heteroskedasticity problem.

For the normality checking, the p-value (0.3744) is greater than all 10%, 5% and 1% significance levels under the Jarque-Bera normality test. Hence, we did not reject the null hypothesis and concluded that the error term in the model 2 is normally distributed. As well, under the Ramsey's misspecification test, the p-value (0.2650) is greater than 10% significance level by using six fitted terms. As a consequence, we did not reject the null hypothesis of the model is correctly specified and concluded that the model is correctly specified at all the three significance level (10%, 5% and 1%). In addition, we test for stability of the coefficients in the estimated Model 2 by using cumulative sum (CUSUM) stability tests. The results (in Appendix) show that the estimated parameters for Model 2 appear to be stable throughout our chosen sample period.

Table 4.4: The estimated ARDL Model Based on Model 2

Panel 2(a)

Variable	Coefficient	T- statistics	Probability
K	0.2525	3.3757	0.0022 ***
L	0.0219	1.8628	0.0995 *
EC	0.2608	2.0141	0.0788 *
TECH	0.5047	3.9862	0.0040 ***
C	0.3589	1.1985	0.2650
Adjusted R-squared	0.9198		
Standard Error of Regression	0.0113		
F-statistic	20.1174		
Probability (F-statistic)	0.0001		

Panel 2(b)

Diagnostic Checking

i) Autocorrelation (Breusch-Godfrey Serial Correlation LM test)

F(1) = 0.1664 [0.6955] F(2) = 0.0733 [0.9302]

ii) ARCH Test

F(1) = 0.8078 [0.3806] F(2) = 0.9236 [0.4173]

iii) Jarque- Bera Normality Test:

χ^2 (2) = 1.9649 [0.3744]

iv) Ramsey RESET Specification Test:

F-statistic= 3.0848 [0.2650]

Note: *, ** and *** indicate variables are significant at 10, 5 and 1 per cent significance level. Figures in squared parentheses [ ] refer to marginal significance level (p-value. All variables tested are in natural log form.

Table 4.5: Bound Test Based on Model 2

Computed F-statistic: 6.4751 ***

Null hypothesis (H_0) : No Cointegration

Decision Rule: Reject H_0 if computed F-statistic value greater than upper bound value. Otherwise, do not reject H_0.

	Critical Value	
	Lower	Upper
1% significance level	3.74	5.06
5% significance level	2.86	4.01
10% significance level	2.45	3.52

Conclusion: Reject H_0 at 1% significance level.

Note: The critical value taken from Pesaran et al. (2001), Table CI (iii): Unrestricted intercept and no trend.

*, ** and *** indicate the model is significant at 10, 5 and 1 per cent significance level.

4.3 Granger Causality Test

4.3.1 Granger Causality for Model 1

Table 4.6 represented the result of Granger causality test between Malaysia's gross domestic product (GDP), capital (K), labour (L), and energy consumption (EC). From the first row of the table, which represents our first model, we can see that there is short run unidirectional causal relationship with direction running from capital to Malaysia's GDP and also energy consumption to gross domestic product, without any feedback effect. In other words, both the capital and energy consumption are found to have impacts towards gross domestic product but gross domestic product does not affect both the variables.

Voser (2012) stated that energy is the oxygen of the economy and this statement is supported by few authors such as Morimoto and Hope (2004), Altinay and Karagol (2005) and Wolde-Rufael (2004). Their studies show that energy is undeniably an engine of economic growth. This is because, without energy, production of good and services might not able to be done hence it will hinder economic growth as production and manufacturing contributes to a large share of GDP. Also, as mentioned in theoretical model, energy is the prime source because labour and capital stock cannot function without using energy. Therefore, energy consumption is an important factor to spur Malaysia's economic growth.

From the Cobb-Douglas production function theory, it is stated that output of economy is affected by capital and this is in line with our result where we found there is unidirectional causality running from capital to Malaysian economic growth. The reason behind is because of capital has become one of the important factors in many sectors to produce goods and services which can help to improve economic growth. For instance, in services sector, it may need computers, telephone, or other machinery to help them to complete a task in order to deliver the services. Thus, investing in capital would help to increase the productivity of growth and therefore it helps to boost up economic growth.

On the contrary, we found that labour does not Granger cause Malaysian economic growth, which is inconsistent with the theory stating that labour is one of the factors that affect economic growth. Supposedly, increase in labour force will increase the country's economic growth. When there are more and more people being employed, the amount of labour force increases and helps to enhance growth. The reason behind is because when people start to earn, they will tend to spend which would help to boost up economic growth. Besides, increase in labour force is vital to production of good and services where it will help to increase the output of economy. However in our case, labour does not affect Malaysian economic growth. One of the reasons might due to the law of diminishing marginal return of labour which happens when more and more labour are being employed and other factor of production remain constant; the productivity of labour will decrease and become inefficient. Therefore, the effect of labour towards economic growth becomes lesser and lesser (Samidi, Abdullah, Ali & Mohaiden, 2008).

Apart from that, Table 4.6 also shows that Malaysian economic growth does not Granger cause any of the independent variables (capital, labour and energy consumption). Not only that, we also found that there is no causality between energy consumption and labour, capital and labour and capital and energy consumption. This means that any impact of the variables will not affect each other.

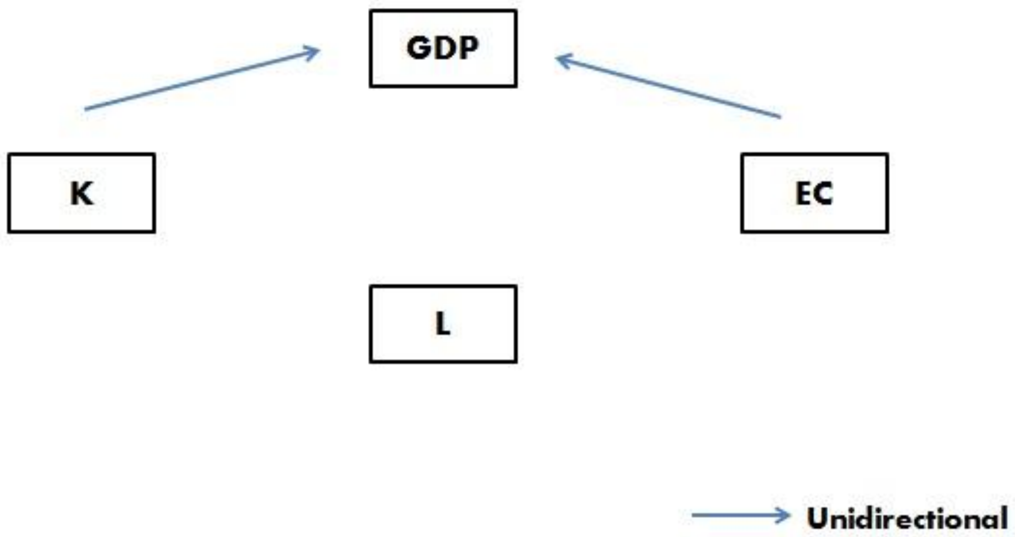
Not to forget, the estimated coefficient of error correction term (ECT) is -0.7172 which is between 0 and 1 for the general equation [GDP = f (K, L, EC)] of Model 1. This indicates that about 72 per cent of this disequilibrium is corrected in one year and it is significant at 1% significance level.

Table 4.6: Granger causality test for Model 1

	ΔGDP	ΔK	ΔL	ΔEC	ECT (t-statistics)
ΔGDP	---	4.8392 **	1.3200	7.7666 ***	-0.7172*** (-3.0645)
ΔK	1.8949	---	0.1768	2.3387	-0.1503 (-0.3247)
ΔL	0.5701	0.2921	---	0.0079	-0.1660 (-0.1451)
ΔEC	1.6472	0.7797	0.1591	---	0.0320 (0.0144)

NOTE: *, ** and *** indicate independent variables are significant at 10, 5 and 1 per cent significance level, respectively. Figures in parentheses are calculated t-statistics.

Figure 4.1: Granger Causality relationship for Model 1



4.3.2 Granger Causality for Model 2

For Model 1, we mainly focus on the linkage between energy consumption and Malaysian economic growth. In our Model 2, we bring in technological factor to examine the role of technology on Malaysian economic growth because as mentioned in Chapter 2 and 3, technology has become one of the important factors to enhance economic growth. From our causality result, we can see that the Granger causality between variables is different from Model 1 after we bring in technology, thus we can conclude that technology brings impact to other variables. Table 4.7 reported the result of Granger causality test between Malaysia's Gross domestic product (GDP), capital (K), labour (L), energy consumption (EC) and technology (TECH).

By referring to Table 4.7, we found that there is bidirectional causality between Malaysian economic growth and technology. In other words, it is two ways causal where Malaysian economic growth Granger causes technology; and technology also Granger causes Malaysian economic growth. The reason behind this is when the income level and standard of living increases, people start to demand more and depend more on technology, which in turns increases investment on technology and help to boost up economic growth (Shiu and Lam, 2008).

In our Model 1, the results shows that there is only one way causal running from capital to Malaysian economic growth. However, after adding in technology, we found a two way causal relationship between capital and Malaysian economic growth. According to Omri and Kahouli (2013), it was found that there is bidirectional causality between gross domestic product and domestic capital and unidirectional causality running from foreign direct investment (FDI) to domestic capital. When domestic capital increases, it will help to boost up country economic growth as explained in Model 1. On the other hand, when a country is experiencing economic growth, investors' confidence tends to increase which would attract FDI inflow to the country that would also contribute to capital inflow. Therefore with an increase in economic growth is likely to increase national capital through attracting more FDI.

Not only that, our result also shows that there is bidirectional causality between capital and technology. The two ways causal relationships between Malaysian economic growth and capital, between Malaysian economic growth and technology and between capital and technology have created an indirect linkage connecting these three variables. For instance, when the country's economic growth increases, it will attract and capture inflow of foreign capital into country which will encourage firms to employ advance technology via capital formation, which in turns helps to enhance economic growth. From the explanation above, we can see that, growth, capital and technology are linked together directly and indirectly (Rahman and Shahbaz, 2011).

Model 1 result shows that energy consumption has causal effect towards Malaysian economic growth. However, after adding technology into our model, energy consumption no longer affect growth but the opposite happens where there is Granger causality running from growth to energy consumption. Thus, it might suggest that Malaysia is no longer so dependent on energy consumption. The unidirectional causality happens when more and more of electricity will be demanded and used when country expands its industrial and commercial sector. Besides, when income and standard of living increases, people will tend to depend more on electric gadget hence increases energy consumption (Ghosh, 2002).

In addition, we also found out that there is causality running from technology to energy consumption. In other word, increase or decrease in investment in technology will give an impact to energy consumption (Jorgenson and Fraumeni, 1981; Røpke, Christensen and Jensen, 2010; Tao, 2011). This can be explained when there is an increase in technology such as internet connections, mobile phones or computers; it will increase the demand for electricity consumption (Sadorsky, 2012). However, increases the use of technology will not necessary increase energy consumption. As stated in theoretical model, technology advancement might decrease energy consumption.

Furthermore, from the result we generated, it shows that capital Granger causes energy consumption. Moreover, from Table 4.7 we can see that, energy consumption did not Granger cause Malaysian economic growth, capital and technology. It was also observed that there is no causality between labour with other variables. In other words, labour will not affect other variables, or vice versa.

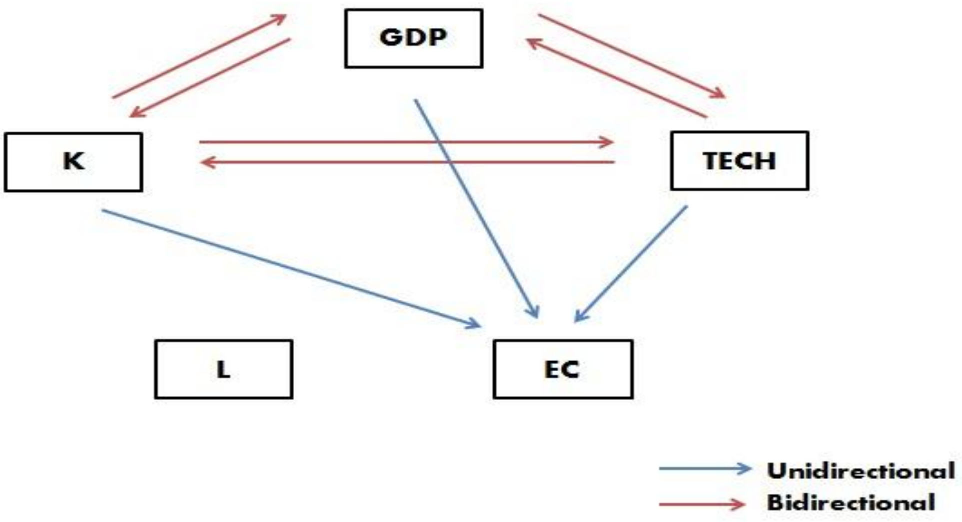
Last but not least, the ECT for general equation [GDP = f (K, L, EC, TECH)] of Model 2 is -2.2257, which is significant at 1% significance level. However, the estimated coefficient is not between 0 and 1 and this might due to we are using unrestricted ECM model to study the short run relationship among the variables. Not only that, Antzoulatos (1996) stated that this problem might due to other explanatory variables in the model generate poor conditional forecasts for the system's endogenous variables.

Table 4.7: Granger causality test for Model 2

	ΔGDP	ΔK	ΔL	ΔEC	ΔTECH	ECT (t-statistics)
ΔGDP	---	4.9791 **	0.6252	0.0334	6.9278 **	-2.2257*** (-3.2201)
ΔK	14.7695 ***	---	0.8226	0.3193	10.8710 ***	-4.0120*** (-4.9297)
ΔL	0.0003	0.0499	---	0.3031	0.2377	-8.5018*** (-3.4585)
ΔEC	21.7262 ***	12.9769 ***	0.0043	---	12.8245 ***	-4.8142 (-0.8267)
ΔTECH	4.3703 *	7.3658 **	0.0018	0.4833	---	-2.0337** (-2.0922)

NOTE: *, ** and *** indicate independent variables are significant at 10, 5 and 1 per cent significance level, respectively. Figures in parentheses are calculated t-statistics.

Figure 4.2: Granger Causality relationship for Model 2



4.4 Chapter Summary

Summing up, based on the empirical results provided by the unit root test and diagnostic checking tests, it can be concluded that both of our models are robust and valid as all variables achieved stationary in first difference form. Our models are also proved to be free from econometric problems. Then, we performed bound test (ARDL approach) to determine the long run relationship between the variables and Granger causality test to determine their short run relationship. By referring to the ARDL approach and Granger causality test, our overall results are considered to be consistent with our hypothesis. All variables have matched our expectation to have positive relationships with Malaysian economic growth. In particular, energy consumption and technology will significantly affect our country's economic performance in both long run and short run.

CHAPTER 5: CONCLUSION

5.0 Summary

One of the focuses of this paper is to analyse the short-run and long-run relationship between energy consumption and economic growth in Malaysia. Unlike previous studies on this subject, we integrate technology into the previous function as an additional explanatory variable to examine its impact on economic growth as well as re-investigating the energy-growth nexus in Malaysia.

To do this, we develop two models corresponding to the Cobb-Douglas production model, both of which incorporate energy consumption as one of their explanatory variables and the latter model we incorporate technology as additional explanatory variable. We employ ARDL and Granger causality test approach to test the long-run and short-run relationship between the said variables respectively, with the sample period from year 1985 to year 2012. The results of the ARDL bound testing approach to cointegration of both models reveal stable long-run relationship between energy consumption and economic growth and also technology and economic growth.

In our first model, we find long-run positive coefficient for energy consumption to be statistically significant at the 10% level, thereby indicating that the energy consumption is positively related to Malaysian economic growth. After we included technology variable into the model, the long-run positive coefficient for technology is statistically significant at 1% level, meanwhile the sign for energy consumption remained the same and also statistically significant at the 10% level. However, the coefficient of energy consumption has dropped more than half which implies that energy consumption might have transferred a portion of its influences to technology. The higher adjusted R-squared of the second model plus the higher significance of technology variable suggest that the economic growth is better explained by technology in the second model. These findings also imply that we should not overestimate the contribution of energy consumption to economic growth. Besides, it is consistent with our expectation that technology is an essential key to stimulate growth.

The results from the Granger causality test provide further explanation on the changes in long-run degree of impact energy consumption brings on economic growth after incorporating technology. In our first model, we find unidirectional granger causality running from energy consumption to economic growth which indicates that Malaysia is an energy-dependent country where energy consumption contributes significantly to economic growth. Therefore, conservation policies or energy crisis will be detrimental to Malaysian economic growth and development. However, after we bring technology into our model, the direction of causality between energy consumption and economic growth has changed. In Model 2, we find opposite causal direction compared to what was found in Model 1, where economic growth granger cause energy consumption. This finding suggests that rising economic growth will increase energy consumption, but not vice versa. In other words, economic growth will not be hampered by conservative policies or energy crisis. Tang and Tan (2012) explain that energy conservative policies will not harm the economic development when there is sufficient technology innovation. This can be the possible reason to explain why the New Economic Model (NEM) sets out plans for Malaysia to adopt the “Polluter Pays” principle by rationalising subsidies and removal of price controls on energy in order to stimulate innovation on energy-efficient technology and preserve the environment. In short, Malaysia has become less energy dependent, as there is no impact of energy consumption on economic growth in the short-run and smaller impact in the long-run, after we bring technology into our model.

Despite the effect of technology on energy-growth nexus, technology itself has direct impact on economic growth and energy consumption. From our empirical analysis, we find bidirectional causality between technology and economic growth in Malaysia. In other words, technology development will stimulate economic growth and vice versa. Not only that, there is unidirectional granger causality from technology to energy consumption. The positive effect of technology on energy use implies that technology in general is energy-consuming rather than energy-saving in Malaysia. Nevertheless, capital formation in Malaysia has similar impact with technology where there is bidirectional causality between capital and economic growth and unidirectional causality from capital to energy consumption. Thus, it is important to highlight that other than its direct impact, economic growth also stimulates energy consumption via its interaction with capital and technology. In short, our empirical findings are suggesting that energy demand is expected to grow significantly as Malaysia is moving towards achieving high income status. This could be one critical inference to explain the projected energy demand-supply gap Malaysia might be facing with after 2020 as mentioned in our problem statement.

5.1 Policy Implication

There are two important policy implications attained from the finding of this study. Firstly, we would discuss the policy implications on energy side. As the Granger causality test results suggest that economic growth can positively impact the energy consumption directly and indirectly, moving towards achieving high income nation status will certainly stimulate energy consumption. Therefore, the Malaysian government should increase investment in energy infrastructure to enhance energy supply for generating economic growth and to also narrow down the energy demand-supply gap. In addition to that, the causality running from capital formation to economic growth suggests that the investment on energy infrastructure which contributes to the capital formation will in turn stimulate economic growth. Since we also have enough evidence from Model 2 to conclude energy consumption does not granger cause economic growth in the short run, the Malaysian government should design short run energy conservation policies to reduce inefficiency or unnecessary wastage of energy consumption. Over the past decades, a series of energy conservation policies have been implemented by the Malaysian government to minimise wastage and promote efficient utilization of energy. Among them are the National Energy Policy in 1979, the National Depletion Policy in 1980 and the Four-Fuel Diversification Policy in 1981 and 1999 (Tang and Tan, 2012).

To be able to maintain our energy supply in the coming decades, policy makers should plan out more Enhanced Oil Recovery (EOR) projects to be carried out in the existing fields to boost oil recovery and production. According to Kokal and Al-Kaabi (2010), deployment of EOR method can maximise ultimate oil recovery. This can extend normal oil field's life by another few decades. Besides, there are now a numbers of small and marginal oil fields both in Malaysia and abroad that is hard to be extracted due to complex geographical factor.

Policy makers should also encourage the use of production sharing contract to attract major players in this industry to collaborate with each other and also with foreign oil companies to extract oil from these small and marginal fields which can also encourage the sharing and development of technical skills. Production sharing contract helps in minimizing government interference and reduce conflicts in parties' interest. Also under production sharing contract, foreign oil company will have more control over its own operation and hence more sharing of technical skill can be done (Ataka, 2013). Furthermore, these production sharing contracts can also encourage more intensified exploration to discover new fields to maintain our country's oil and gas production. Other than that, government should also outline a policy to encourage the sales of energy-efficient appliances for household and energy-efficient machineries for businesses. Rebates could be given out to those who are supportive of such policy. Policy makers should also put in more emphasis in building up the renewable energy capacity in Malaysia. These include promoting the usage of renewable energy and identifying new renewable energy.

Moving on to the technology side, the result of causality can help the government to set the priorities right in using limited resources on desirable industries which benefit the most to the nation. If the empirical results support the technology-led growth hypothesis, the government should allocate more resources to the technology industry before other industries. If the economic growth-led technology development holds true, the government should allocate its resources to other leading industries and not technology industries directly so that overall economy will be improved and the technology industries will benefit from the economic growth. In Malaysia, we have found bidirectional causality between technology and economic growth which means focusing on either technology industry or other key contributing industries in a national are both beneficial towards the nation. Still, Malaysian government should continue to emphasize in developing technology industry, notably the energy efficiency-promoting technology. This is because the energy-efficient technology will not only reduce the energy consumption but at the same time improve economic growth through increase in productivity (Cho, Lee and Kim, 2007). Therefore, energy-efficient technology could simultaneously boost economic growth and minimize degradation which would contribute more social benefits than other industries.

The government can support the research and development directed on making innovative energy-efficient technology by the form of direct government R&D expenditure or public-private partnerships.

Other than pumping financial aids to innovate energy-efficiency technology, attracting constant inflow of foreign direct investment is imperative to bring in existing advanced technology. Policy makers should outline policies in tackling the congestion issues and quality of Malaysia's Internet bandwidth. In this highly digitised era, businesses are very dependable on the Internet services to deal with daily transaction. With faster speed and more stable Internet, Malaysia can to attract more foreign corporations to set up their counterparts in the country. Furthermore, policy makers should aim to make government service 100% online. We believe this is necessary as making government services online can ease the hectic procedures needed especially when it comes to business applications and related activities. By having friendlier business environment or investment climate, FDI is expected to be increased (Nnadozie and Njuguna, 2011). This in turns will bring in more technological spillover.

5.2 Limitation of the Study

Based on our research, we found that there are few limitations to be proposed for further studies. Small sample size of data would be one of them in our study. Theoretically, in order to get a more accurate result, larger sample size of data is required in order to minimize the error terms and have higher possibility to get statistical significance (Rhiel and Chaffin, 1996). Unfortunately, we are only able to obtained yearly data ranging from year 1985 to 2012, which is in total of 28 observations that can be considered as a small sample size of data. This is due to lack of data for our main variables (energy consumption and technology).

The data for both of these variables can only be found starting from 1985 to 2012. Therefore, we are forced to only include 28 years of data in our study.

Small degree of freedom then became our limitation in our research in relation with the small sample size of data that we can obtain. The limited data that we can obtain has caused degree of freedom in our model to become lesser and lesser after ARDL estimations as a result of the extensive use of lagged variables. Although we are only able to obtain small sample size of data in our model, in order to avoid getting undesirable results, we put effort in choosing the most suitable tests to get accurate results and to minimize these problems in our model. Therefore, we had conducted PP test to determine the level of stationary of variables and ARDL Bound test to determine the long run relationship between variables. The reason is that both of these tests are suitable for our model which only consists of only 28 observations compared to other test. The employment of these two tests has ensured that the problems of the small sample size towards our model are eliminated.

In Chapter 4, the Granger causality test shows that labour has no causality with other variables in both Model 1 and Model 2. The reason for this might be because of the proxy that we choose is the amount of student enrolment into tertiary education. We have faced problem in obtaining full set of data for labour force variable which leads to the second best alternative of taking student enrolment as proxy instead of using total labour force. There is a possibility that we might get different Granger causality result if we used total labour force as our proxy. Nevertheless, our result is still justifiable with the theory of law of diminishing marginal return of labour that we have explained in Chapter 4.

5.3 Recommendation for Future Study

The data of technology variable that we have employed in our model is the total R&D expenditure contributed by the whole nation, from both private and public sectors. Therefore, we can only see the general R&D effect on economic growth and energy consumption but not the individual impact of every single industry. The positive impact of technology on energy consumption shows that the employment of energy-consuming technology dominates the presence of energy-efficient technology in Malaysia. This can only suggest that energy-efficient technology in Malaysia is not widely adopted yet in general but not in which specific industry. Therefore, we suggest other researchers that use R&D expenditure as a proxy for technology variable to be narrowed down to categorise the portion of expenditure spent in different industries. Upcoming studies should try to breakdown the total R&D expenditure to obtain the proportion of money allocated in each industry in Malaysia and study its impact on energy consumption and economic growth. The rationale behind this is to allow policy makers to have a clear direction in outlining proper technology-promoting policies for the identified key industries that adsorb more impact from technology advancement and hence promoting more economic growth. Not only that, it is necessary to identify what are the industries that employ more energy-consuming technology in order to formulate effective energy conservative policy to reduce the uprising energy demand. However, such secondary data might not be available in various databases. Thus, researchers might have to collect primary data of such information for the benefit of it.

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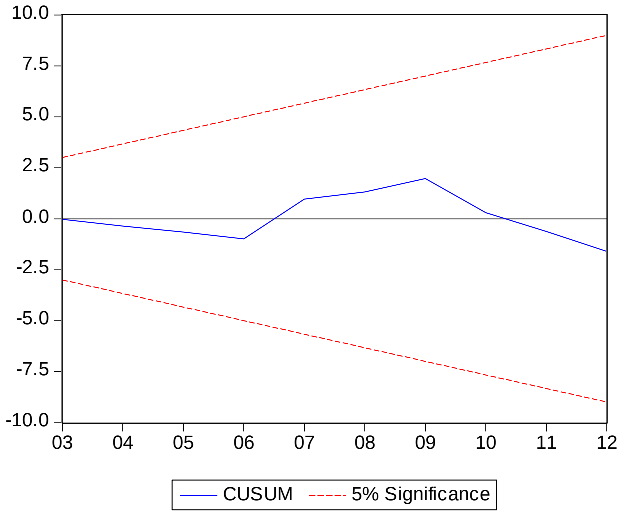
APPENDIX

Plot of Cumulative Sum of Recursive Residuals for Model 1



Plot of Cumulative Sum of Recursive Residuals for Model 2