ANALYSIS ON THE RELATIONSHIP BETWEEN SECTORAL ELECTRICITY CONSUMPTION, ECONOMIC PERFORMANCE AND ELECTRICITY PRICE IN MALAYSIA

By

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ABSTRACT

Electricity is one of the important sources of energy and is vital for the process of the country's economic growth. The issues of growing electricity consumption and heavy electricity subsidies have raised the attention of the government. However, the majority of the previous studies that specialize on the demand side of electricity were focused on total electricity consumption. Thus, this paper aims to provide the background analysis of electricity consumption trends with the focus on the four main economic sectors in Malaysia such as the industrial, commercial, mining and agricultural. The purposes were to examine the relationship between electricity consumption, Gross Domestic Product (GDP) and price of electricity based on panel data for the period 2002 to 2012. The sectoral electricity consumption model was tested using econometric techniques such as Panel Cointegration, Panel Fully Modified Ordinary Least Square (FMOLS) and Panel Granger Causality tests. The Panel Cointegration Test confirmed an existence of a stable long run relationship among the variables. The results from the panel FMOLS estimation revealed that the electricity consumption in industrial, commercial and mining sectors was positively responsive to GDP changes. In the agricultural sector, GDP had a negative effect on electricity consumption. Moreover, the higher electricity price tended to increase and decrease electricity consumption in the industrial sector and commercial sector respectively. Nonetheless, the results of the electricity price were not significant in the mining and agricultural sectors. For all the sectors, an increase in GDP had a positive effect on electricity consumption. Finally, the Panel Granger Causality Test detected a relationship running from economic growth to electricity consumption. The results obtained indicated that policy maker must be careful in the formulation of energy policy, thus suggesting that the policy should be focused on the electricity consumption in each sector.

ABSTRAK

Elektrik merupakan salah satu sumber tenaga yang penting dan memainkan peranan dalam proses pertumbuhan ekonomi negara. Isu-isu mengenai peningkatan jumlah penggunaan tenaga elektrik dan subsidi elektrik yang tinggi telah mendapat perhatian serius Kerajaan. Bagaimanapun, kebanyakan kajian terdahulu yang mengkhususkan pada sudut permintaan elektrik lebih terarah kepada penggunaan elektrik secara menyeluruh. Maka, kertas kajian ini akan memberi tumpuan kepada analisa corak penggunaan elektrik dengan fokus diberikan kepada empat sektor ekonomi utama di Malaysia iaitu perindustrian, komersial, perlombongan dan pertanian. Tujuannya adalah untuk mengkaji hubungan di antara penggunaan elektrik, Keluaran Dalam Negara Kasar (KDNK) dan harga elektrik berdasarkan pada data panel bagi tahun 2002 hingga 2012. Model penggunaan elektrik oleh sektor-sektor terbabit dijalankan menggunakan teknik-teknik ekonometrik seperti Panel Kointegrasi, Panel Pengubahsuain Penuh Kaedah Kuasa Dua Terkecil (FMOLS) dan Panel Penyebab Granger. Hasil ujian Panel Kointegrasi mengesahkan bahawa terdapatnya hubungan jangka panjang antara pembolehubah-pembolehubah tersebut. Keputusan daripada Panel FMOLS menunjukkan bahawa penggunaan elektrik di sektor perindustrian, komersial dan perlombongan adalah responsif secara positif terhadap perubahan KDNK. Di sektor pertanian, KDNK memberi kesan negatif ke atas penggunaan elektrik. Selain itu, kenaikan harga elektrik cenderung untuk meningkatkan dan mengurangkan penggunaan elektrik masing-masing di sektor perindustrian dan komersial. Walau bagaimanapun, hasil keputusan tersebut adalah tidak signifikan ke atas sektor perlombongan dan pertanian. Untuk semua sektor pula, peningkatan KDNK memberi kesan positif ke atas penggunaan elektrik. Akhir sekali, ujian Panel Penyebab Granger mengesan terdapatnya hubungan daripada pertumbuhan ekonomi kepada penggunaan elektrik. Keputusan yang diperolehi ini menunjukkan bahawa pembuat dasar haruslah berhati-hati dalam menggubal dasar tenaga, sekaligus mencadangkan supaya dasar yang dibuat perlulah bersandarkan kepada penggunaan elektrik oleh setiap sektor.

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Glory to Allah S.W.T, the Most Gracious, the Most Merciful and peace upon His Messenger Holy Prophet Muhammad S.A.W. All the worship belongs to only Allah. I also give praise to Allah S.W.T for giving me strength, patience and knowledge to complete this program successfully.

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Mohd Hafiz Aswad bin Nadzri

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LIST OF ABBREVIATION

ADF	Augmented Dickey-Fuller
ASEAN	Association of South-East Asian Nations
Sen/kWh	Sen per kilowatts hour
CI	Capital Investment
CONS	Number of Consumers
CPI	Consumer Price Index
EC	Electricity Consumption
ECM	Error Correction Model
ECT	Error Correction Term
EMP	Employment
FMOLS	Fully Modified Ordinary Least Square
GDP	Gross Domestic Product
GW	Gigawatts
GWh	Gigawatts per hour
IEA	International Energy Agency
IPP	Independent Power Producer
kWh	kilowatts per hour
LLC	Levin, Lin and Chu
MIEEIP	Malaysian Industrial Energy Efficiency Improvement Project
MW	Megawatts
OLS	Ordinary Least Square
PE	Price of Electricity
RE	Renewable Energy
SEB	Sarawak Energy Berhad
SESB	Sabah Electricity Sdn Bhd

SUR	Seemingly Unrelated Regression
TNB	Tenaga Nasional Berhad
TWh	Terawatts per hour
UK	United Kingdom
US	United States

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Electricity is a man-made source of energy. As it is non-durable, electricity compliments durable goods like electrical appliances or electrical machinery (Rebensteiner, 2013). It helps directly by running consumer durables in terms of services and running machines which help directly or indirectly to produce consumer goods. Electricity is an exceptional energy because the consumption of electricity has to be simultaneous once it is been generated, thus electricity cannot be economically stored. Furthermore, electricity has a unique position among other different types of energy because electricity is clean energy, is easy to transfer and can be transformed into other kinds of energy. The demand of electricity varies hourly, daily, weekly and across the seasons (Ranci & Cervigni, 2013). It cannot be fully controlled and it is practically impossible to prevent market participants from consuming more or less electricity.

Electricity plays an important role in the process of economic growth and is required for both commercial and non-commercial usage. Commercial usage of electricity refers to the use of electric power in the industrial, commercial, mining and agricultural sectors. For non-commercial, the principal use of electricity energy is for public lighting and by residential consumer. Winkler, Simoes, Rovere, Rahman & Mwakasonda (2011) stated that electricity is a vital input together with machinery, land, natural resources and human capital in the productive base of the economy. It is indispensable to industrial and commercial establishments, meaning that a lack of energy causes difficulties and economic losses due to the reduction in production (Chouaibi & Abdessalem, 2011). Moreover, an increase in the production of goods and services will consume a lot of electricity. Therefore, the demand for electricity is driven by such important factors as industrial development, population growth, urbanization and the rising standard of living. This is why electricity has become the principal type of energy source to improve the socioeconomic condition in countries (Kanagawa & Nakata, 2008).

The increasing trend of electricity consumption and its relationship with the growing economy has come to the special attention of policy makers. In Malaysia, electricity demand is mostly met with the use of insufficient and expensive fuel resources such as natural gas and coal which continues to expand rapidly. At the same time, it is the government's responsibility to supply a sustainable and economical price of electricity to consumers. However, the lack of sufficient generation to meet the increasing demand for electricity in the country will lead to undesired political, social and economic effects. Therefore, an understanding of consumers' demand behaviour on electricity is important in order to have an accurate planning for the sufficient supply of electricity commensurate with this demand. Furthermore, it is vital to have comprehensive knowledge of factors that influence electricity consumption. This information could be useful for policy makers to come out with better energy policies and strategies to minimize the socioeconomic effects such as their impact on firms, households, and consequently, social welfare.

1.2 BACKGROUND OF THE STUDY

This section consists of three sub-sections where Section 1.2.1 is an overview of electricity in Malaysia, Section 1.2.2 explains the electricity consumption among individual sectors, and lastly, Section 1.2.3 explains electricity pricing in Malaysia.

1.2.1 Overview of Electricity in Malaysia

Electricity first made its appearance in this country at the turn of the 20^{th} century, and the earliest record of power generation can be traced to a small mining town in Rawang. In 1894, an electric generator was installed and it was first used to power electric pumps for mining in Malaya. This marked the great beginning of the journey of the electricity industry in Malaysia. Generally, electricity passes through three level phases, from power generation to transmission grids before it reaches to the final consumer using distribution lines. In Malaysia, three power utility companies such as Tenaga Nasional Berhad (TNB) in Peninsular Malaysia, Sabah Electricity Sdn. Bhd. (SESB) in Sabah and Sarawak Energy Berhad (SEB) in Sarawak hold a monopoly in these three level processes. These power utilities undertake electricity generation, transmission, distribution and supply activities in their respective areas. Since the blackout incident in 1992, the government has opened Independent Power Producers (IPPs) to participate in the power generation sector by supplying electricity to utility companies under a privatization policy. YTL Power Generation Sdn Bhd had the first IPP licence in 1993 to operate two power plants in Paka, Terengganu and Pasir Gudang, Johor with a combined installed capacity of 1,170 megawatts (MW). As of December 2012, Malaysia has a total installed capacity of electricity generation of 29,143 MW (*National Energy Balance,* 2012).

The past decade has witnessed the electricity sector experience a substantial growth in tandem with the growth of the economy. Since independence in 1957, Malaysia inherited a commodity based economy largely relying on rubber and tin. In 1985, the industrialization plan was implemented resulting in a structural shift from an agricultural to a manufacturing and service based economy (Ponniran, Mamat & Joret, 2012). This was a push for heavy industries with several key projects including the national car project, the refinery and petrochemical industry, iron and steel billets, cement industries as well as pulp and paper industries. Apparently, each of the heavy industries requires a large amount of electrical energy in order to operate. As a result, this major push was the essential factor in the steep increase in demand for energy, particularly electricity. In 2012, electricity constituted about 21.4 percent of Malaysia's final total energy consumption after petroleum products and natural gas at 53 percent and 21.8 percent respectively, followed by coal at 3.7 percent (*National Energy Balance*, 2012).

Figure 1.1 illustrates the comparison between electricity demand and electricity production in Malaysia. It can be observed that electricity production remained short to cope with the required electricity demand from 1990 until 2002. Since then, this gap has widened with the passage of time and expanded further until 2012. Nevertheless, from 1990 until 2012, electricity production has always exceeded the demand for electricity, ensuring that power sectors have the capacity to provide electricity to customers. According to the Energy Commission, the demand for electricity should not exceed the amount of electricity that a power generation can produce at any given time.

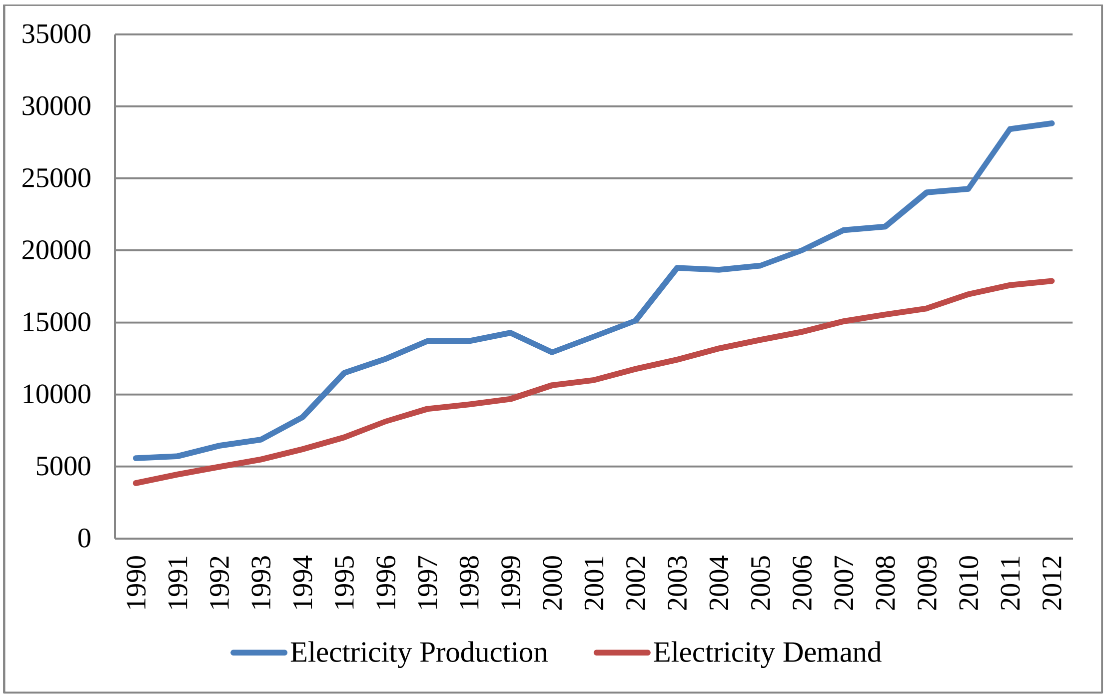

Figure 1.1
Electricity Production and Electricity Demand in Malaysia (MW)
Source: Energy Commission, National Energy Balance 2012

Traditionally, Malaysia's energy sources for electricity production or generation are based on a four fuel mix strategy namely natural gas, oil, hydro and coal. In the early 1980s, oil was relied on heavily for electricity generation which led to rapid depletion of oil in Malaysia. Between 1992 and 2012, the sources of fuel for electricity generation were further diversified with natural gas and coal increasingly being relied on as primary fuels as illustrated in Figure 1.2. In response to the limited supply of local gas and oil reserves, efforts were undertaken by the government to reduce the high dependence on both fuels in the electricity generation mix by increasing the use of coal. As a result, the share of coal in the total generation mix increased tremendously from 13 percent in 1992 to 41 percent in 2012, whereas natural gas increased from 38 percent to 46 percent for that respective year (*Malaysia Energy Statistic Handbook*, 2014). This was consistent with Malaysia's energy policy strategy to ensure security and reliability of electricity supply. While coal is seen as the cheapest fossil fuel for generating electricity, it is also the dirtiest because of its highest levels of pollutants into the environment. In 1999, the government introduced Five Fuel Diversification Policy with renewable energy (RE) as the fifth source for electricity generation. Under the Eighth Malaysia Plan, RE was targeted to contribute five percent of the total energy mix by 2010 with promising potential of RE coming from biomass and biogas from the oil palm industry.

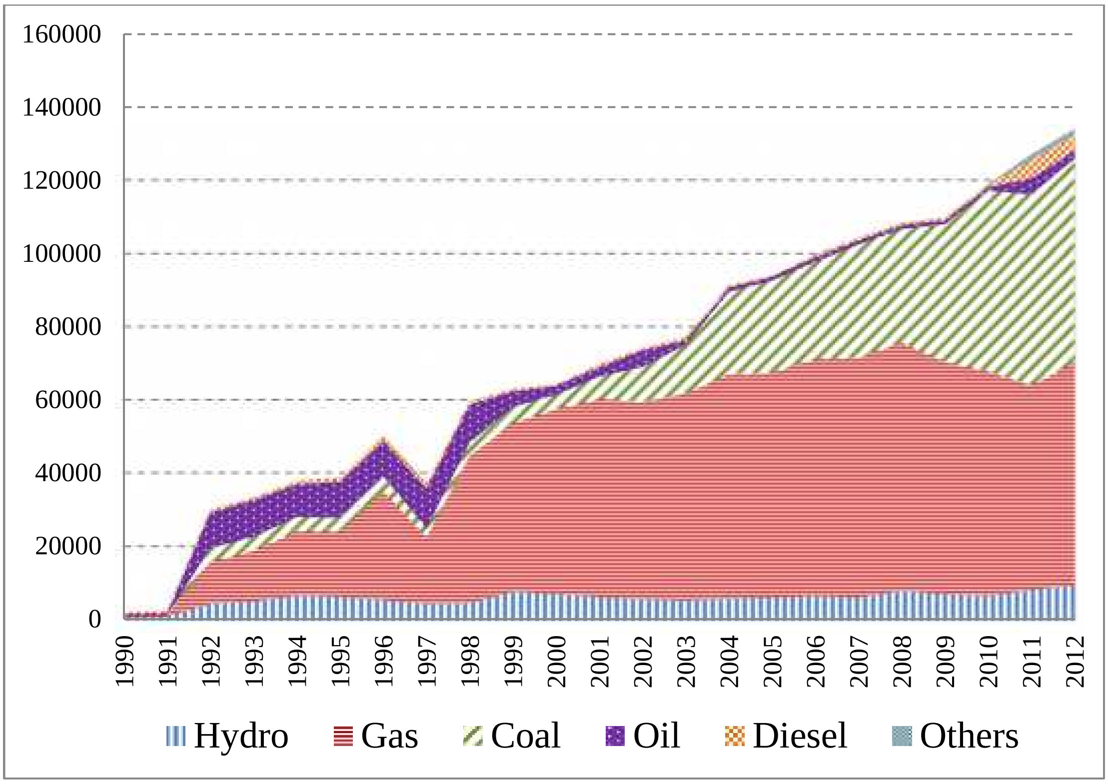

Figure 1.2
Electricity Generation Mix in Malaysia (GWh)
Source: Energy Commission, Malaysia Energy Statistic Handbook 2014

Malaysia has one of the highest rates of electricity consumption per capita within the Association of South-East Asian Nations (ASEAN) developing countries (Tang, 2009). As illustrated in Figure 1.3, the demand for electricity per capita increased from 657 kilowatts per hour (kWh) in 1980 to reach its highest verge of 4,136 kWh in 2010. It can be observed that there was an increasing pattern of electricity consumption per capita by an annual average of six percent growth. The increment was a result of increasing industrialization and population growth which led to consumption of electricity in Malaysia rising faster than that in other developing countries in ASEAN.

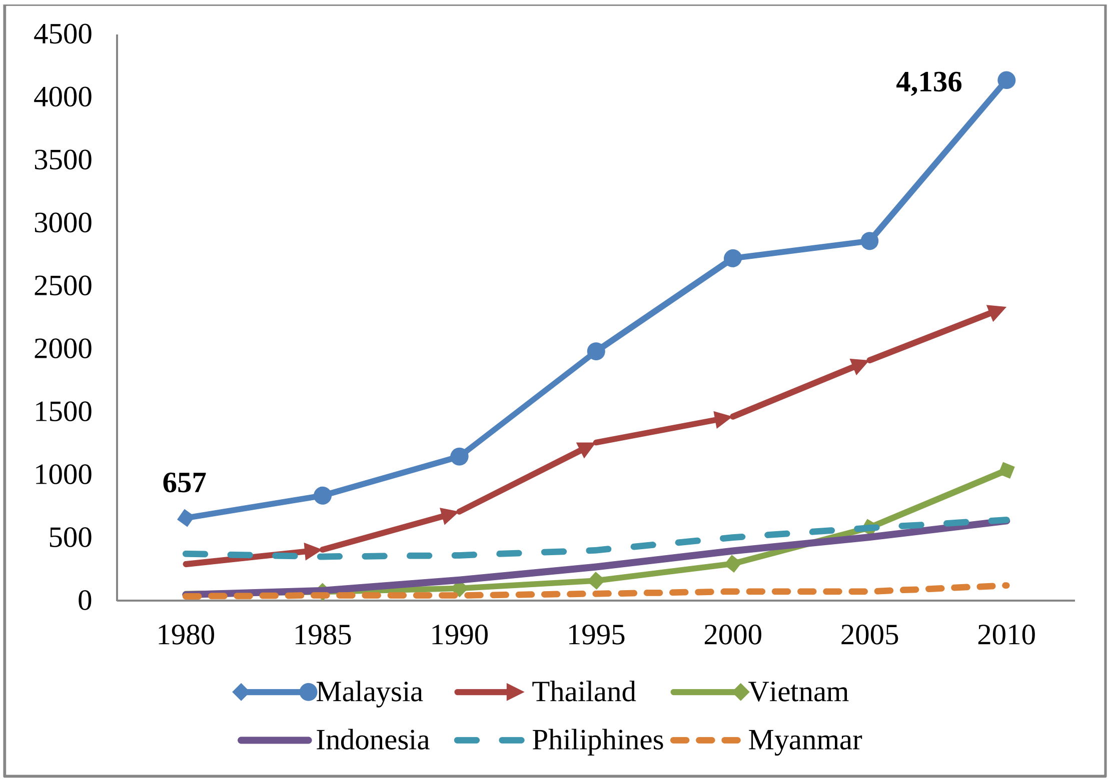

Figure 1.3
Electricity Consumption Per Capita in ASEAN developing countries (kWh)
Source: The World Bank, 2014

According to the Performance Management Delivery Unit, the country will need more electricity by 2020 with additional six gigawatts (GW) of new installed capacity for electricity generation ("Powering the Malaysia Economy with Oil, Gas and Energy", 2013). Furthermore, the International Energy Agency (IEA) forecasted that from the period 2011 until 2030, the demand for electricity in Malaysia is expected to double and increase further to 300 terawatts per hour (TWh) in 2035. (*Southeast Asia Energy Outlook*, 2013) This requires an expansion of installed capacity for electricity generation from 29 GW in 2011 to 67 GW in 2035.

Tang (2009) indicated that the demand for electricity is growing in tandem with its Gross Domestic Product (GDP) growth, where electricity stimulated economic growth in Malaysia. By observing the growth rate for both electricity consumption and GDP, as shown in Figure 1.4, it can be easily deduced that the annual growth rate for electricity consistently exceeds the annual GDP growth. The electricity consumption increased at an annual average of 13 percent and 5.7 percent growth rate, between 1990 and 1996 as well as 1999 and 2007. Within the same period, Malaysia's economy also increased by an annual average of 9.5 percent and 5.6 percent growth rate. However, a slowdown of the economy was observed between 1997 and 1998 due to the Asian financial crisis and global financial crisis in 2008 and 2009. Because of Malaysia's strong economic resilience, the country was able to endure the crisis when the economy showed a strong recovery and the amount of electricity consumption increase substantially. This proves that electricity consumption plays an important role in Malaysia's economic development.

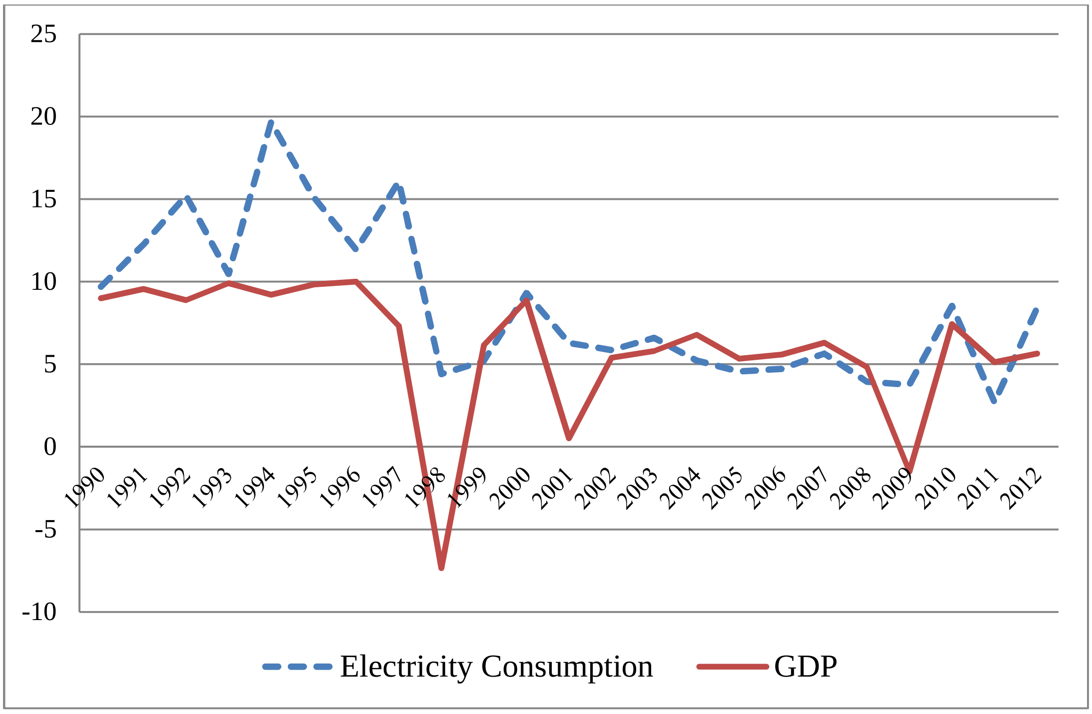

Figure 1.4
Annual Growth Rates between Electricity Consumption and GDP
Source: Energy Commission, Malaysia Energy Statistic Handbook, 2014

1.2.2 Electricity Consumption by Economic Sectors

The demand for electricity in Malaysia is primarily for the industrial, commercial, residential, public lighting, mining and agricultural sectors. The factors that derive electricity demand differ across the economic sectors. For instance, the industrial and commercial sectors consume electricity as an input of production and their objective is to minimize the cost of production. Residential consumers' demand for electricity relies on consumers' utility maximization by allocating income so that they obtain great satisfaction from total expenditure.

As depicted in Table 1.1, the industrial sector is the main electricity consumer, accounting for more than 40 percent of total electricity consumption in Malaysia. The commercial sector is the second largest electricity consumer at just below 35 percent, followed by the residential sector at around 20 percent. By comparison, other sectors such as public lighting, and the agricultural and mining sectors made up less than two percent of total electricity consumption. To investigate the behaviour of electricity consumers among the sectors, this study will emphasize the commercial usage of electricity referring to the four key sectors in Malaysia's economy, namely the industrial, commercial, mining and agricultural sectors. These sectors contribute significantly to the development of Malaysia's economy in terms of GDP and use electricity energy as an input to produce goods and services. Meanwhile, other sectors such as residential and public lighting are not considered in this analysis because these sectors consume electricity for non-commercial purposes and do not contribute to the country's GDP.

Table 1.1
Final Electricity Consumption by Sectors

Sector	**2002**		**2008**		**2012**	
	GWh	*%*	**GWh**	*%*	**GWh**	*%*
Industrial	33,374	*51*	43,254	*46.8*	46,989	*43*
Commercial	18,896	*28.9*	29,757	*32.2*	37,167	*34*
Mining	64	*0.1*	34	*0*	98	*0.1*
Agricultural	1	*0*	214	*0.2*	344	*0.3*
Residential	12,435	*19*	18,032	*19.5*	23,321	*21.3*
Public Lighting	696	*1.1*	1,069	*1.2*	1,367	*1.3*

Source: Energy Commission, National Energy Balance 2012

1.2.2.1 Industrial Sector

The industrial sector can be defined as a consumer engaging in the manufacturing of goods and products. The industrial sector represents both the manufacturing and construction sectors. The chemical, base metal, paper, wood, non-metal and food industries are the most energy-intensive users in the industrial sector (Saidur *et al.* 2007). Overall energy use in this sector is largely for processing heat, cooling and powering machinery. Table 1.1 shows that the industrial sector has the largest share of electricity usage in overall electricity consumption but its share slowly reduce from 51 percent to 43 percent between the period 2002 and 2012. It can be observed that in the future, electricity consumed by the industrial sector will not only decrease but could also diminish. The reason could be from the energy efficiency measures that were implemented by industrial consumers, which managed to reduce the energy demand (*National Energy Balance*, 2012). Meanwhile, industrial electricity consumption has recorded a 6.9 percent growth from 2002 to 2012. One of the main reasons for the higher growth was due to the performance of the GDP growth rate in the construction sector that is driven mostly by energy intensive industries (*National Energy Balance*, 2012).

In order to understand the efficiency of electricity usage relatively to the performance of the economy, this study uses the term energy intensity as a measurement for the quantity of energy required per unit of economic output or GDP. As illustrated in Figure 1.5, the industrial sector recorded the highest electricity intensity compared to other sectors in the economy. Industrial electricity intensity slowly decreased by 8.4 percent from 2005 to 2012. In other words, the required electricity for producing one unit of GDP was 23.86 gigawatts per hour (GWh) in 2005 but then it fell to 22.02 GWh in 2012. The reduction of electricity intensity in the industry may be due to the fact that producers on average are becoming more efficient at producing the finished products, or producers are shifting production towards finished products that require less energy (Saidur *et al.* 2007).

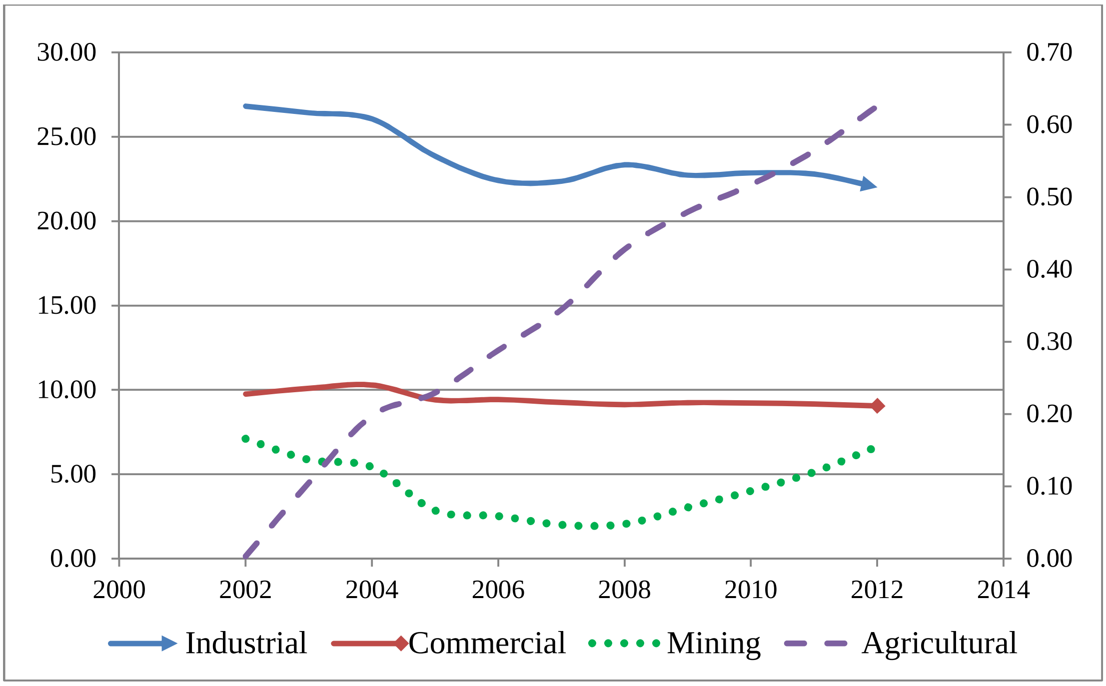

Figure 1.5
Electricity Consumption Intensity by Sectors (GWh/GDP)
Source: Energy Commission, Malaysia Energy Statistic Handbook 2014

1.2.2.2 Commercial Sector

The commercial sector is defined as a consumer occupying or operating in the buildings used by businesses or other organizations to provide workplaces or gathering spaces or offer services. Also known as the service sector, this sector includes service businesses such as shops and stores, hotels, restaurants, airports as well as a wide range of facilities such as government buildings, religious organizations and any other forms of businesses or commercial activities which are not primarily involved in manufacturing, quarrying or mining activities. According to IEA, the common use of energy associated with this sector includes space heating, water heating, air conditioning, lighting, refrigeration, cooking and running a wide variety of other office equipment. According to the total number of electricity consumers, the commercial sector is the second largest consumers after the residential sector, accounting for 1.5 million or 17 percent of the total electricity consumers in 2012 (*Electric Supply Industry in Malaysia*, 2012).

Since the last decade, the commercial sector has experienced higher growth in electricity consumption and this trend has kept increasing for many years now. Kinuthia (2011) argued that the commercial sector was the main driver for Malaysia's economic growth during an economic boom in the late 20^{th} century, which could explain this growing trend. As depicted in Table 1.1, the growth rate of commercial electricity consumption from the period 2002 to 2012 is estimated at 96.7 percent. The increasing trend of electricity consumption was attributed to the expansion in hypermarkets and retail outlets coupled with the extension of tourism activities and Malaysia mega sales events (*National Energy Balance*, 2012). Meanwhile, electricity intensity in the commercial sector was consistent throughout the years as illustrated in Figure 1.5. This pattern was contributed by the increase in the usage of electrical appliances and equipment concurrently with the growth of commercial economic activities (Ponniran, Mamat & Joret, 2012).

1.2.2.3 Mining Sector

The mining sector can be defined as a consumer using most part of the electricity for extracting minerals and dredging activities for crude oil, natural gas and tin. This sector contributed the lowest share of total electricity consumption at 0.1 percent. As shown in Table 1.1, electricity consumed by the mining sector declined from 2002 until 2008, but then it slowly increased beginning in 2010. Moreover, the mining sector's contribution to GDP growth also started to decline within the same period due to lower production of crude oil and natural gas, as well as the shutdown of a number of oil fields for maintenance which led to lower activity in the mining sector (*The Malaysia Economy*, 2006). As illustrated in Figure 1.5, the mining sector's electricity intensity pattern displayed at almost a constant trend between 0.17 GWh and 0.15 GWh from 2002 until 2012.

1.2.2.4 Agricultural Sector

The agricultural sector is a consumer conducting specific agricultural activities strictly related to agricultural cultivation and breeding. Electricity used in the agricultural sector is used mainly to operate machinery and equipment, heating or cooling green houses, lighting in the farms, water pumping for the irrigation of land and controlling water gates for the production of grains. In comparison to other sectors in the economy, the agricultural sector has become increasingly dependent on energy resources. This sector was relying more on petrol and the coal industry output as its input compared to electricity and natural gas (Abdullah & Bekhet, 2010). It is observed that the agricultural sector only contributes a smaller share of the total electricity consumption, accounting for less than 0.5 percent. As depicted in Table 1.1, electricity consumed by the agricultural sector increased from one GWh to 344 GWh from 2002 until 2012. The growth in electricity consumption is in line with the GDP growth rate in the agricultural sector during the same period. As a result, agricultural electricity intensity has gradually increased from 2002 to 2012 reaching at 0.63 GWh.

1.2.3 Electricity Pricing in Malaysia

In Malaysia, the price of electricity or electricity tariff is regulated and administered by the government, where economic, social and political considerations play an important role in price determination. According to the Energy Commission, there are three cost components in determining an electricity tariff, namely generation cost, transmission cost and distribution cost. The generation cost consists of the fuel cost and the capacity charge cost which contributes approximately 74 percent of the total electricity cost. This is followed by transmission cost at seven percent and distribution cost at 19 percent. Based on the cost structure of the electricity tariff, an increase in generation cost, specifically rising in fuel cost, will have the biggest on the electricity tariff. According to the President of the Association of Water and Energy Research, Malaysia, fossil fuels remain the highest cost for the electricity industry as their price continues to rise (“Energy Efficient The Way Forward”, 2011). It is observed that natural gas and coal are two major components that affect electricity tariffs (*National Energy Balance*, 2012).

Since 1997, the electricity tariff had remained unchanged until 2005. A new price schedule was established in 2006 when the government approved a new tariff hike on an average rate of RM25.90 sen per kilowatt hour (sen/kWh) as a base tariff adjustment. Thereafter, in 2008, there was an increase in the electricity tariff on an average rate RM28.80 sen/kWh due to the impact of rising natural gas tariffs. The government then reduced the electricity tariff in 2009 when there was a reduction in fuel price. In 2011, the government decided to increase the electricity tariff on an average rate of RM29.10 sen/kWh. This increment was due to the government objective to reform the electricity price by removing subsidies under the energy subsidy rationalization exercise.

Figure 1.6 illustrates the average electricity tariff imposed in four main sectors in the economy. Currently, the retail electricity price for all levels of consumption is below the cost price. The government fuel subsidies, especially natural gas that is supplied by Petronas and the coal price fluctuation impact on tariffs absorbed by TNB, have been successful in keeping the electricity tariffs low. This can be shown between the period 2000 and 2006, when the average electricity price remained relatively stable. However, these combustion fuels have become more expensive while the government is facing the constraint with a fiscal deficit. Considering these factors, there was a hike in electricity tariff in 2008 which had an impact on all electricity users. It can be observed that the mining and agricultural sectors show a major adjustment in electricity price compared to the industrial and commercial sectors.

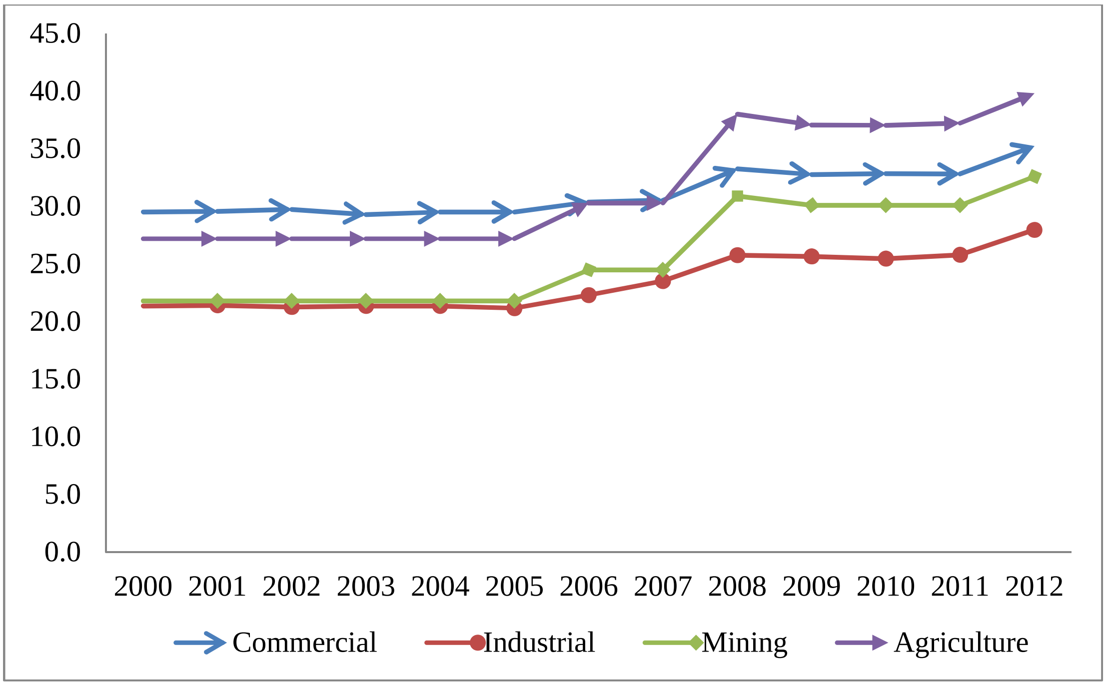

Figure 1.6
Average Electricity Price by Sectors (sen/kWh)
Source: Energy Commission, Electricity Supply Industry in Malaysia 2002-2012

1.3 PROBLEM STATEMENT

Electricity plays a key component as an energy input with the importance of stimulating technological and socioeconomic development. Thus, electricity is important for the growth of the economy and the country's prosperity (Alter & Syed, 2011). In Malaysia, the demand for electricity is growing in tandem with its GDP growth. The growth for electricity showed an increase of 4.7 percent in 2012 compared to 3.9 percent in 2002, driven by strong demand from the industrial and commercial sectors. It is expected that the demand for electricity is going to be double in 2035, thus requiring an expansion of installed capacity for electricity generation. Furthermore, the government financial burden is expected to increase through the heavy electricity subsidies and a lower electricity tariff leads to over consumption among electricity industries and consumers.

In order to overcome these phenomena, the government had developed long term energy policies and strategies, where among the objectives were to encourage the efficient use of energy among industries and consumers through the development of green technology and reviewing the electricity tariff structure as a means of attracting high quality investment (*10th Malaysia Plan*, 2010). According to Ivy-Yap & Bekhet (2014), many economists believed that an increase in the electricity tariff was due to insufficient fuel resources and this will stimulate technological progress. However, the task of implementing these policies does not suffice due to the fact that Malaysians are highly dependent on electricity in the production of goods and services (Chandran, Sharma & Madhavan, 2010). This has been given special attention by analysts, researchers and policy makers to analyze how the quantity of electricity consumed changes in response to economic factors such as the GDP and the price of electricity.

In Malaysia, research on electricity consumption under the economic perspective is rather limited to Tang (2009), Chandran *et al.* (2010), Lean & Smyth (2010), Bekhet & Othman (2011) and Ivy-Yap & Bekhet (2014). Despite their studies on the relationship between electricity consumption and some macroeconomic variables such as GDP and population, they actually ignored to include the real electricity price as an important determinant of the electricity consumption function. It has been found that Bekhet & Othman (2011) and Ivy-Yap & Bekhet (2014) apply the consumer price index (CPI) as a proxy for the price of electricity. Even though CPI may constitute a good indicator to measure the average price changes in goods and services, it has a limitation due to the fact that CPI is based on a fixed weighted index rather than a relative quantity purchased by consumers (Miller, 1994). This provides inconsistent results where both literatures found that the price of electricity was insignificant to explain the electricity demand.

To avoid the limitations in measurement, this study's contribution is to fill the existing gap in the literature relating to investigations of the impact of real electricity price on electricity consumption. Real electricity price is based on the average electricity tariff obtained from the Energy Commission. As suggested by Kamaludin (2013), the adoption of real electricity price could offer more accurate measures to explain consumer responses to price change. In addition, this study also aims to examine the effect of GDP or economic output on electricity consumption.

Nevertheless, this research is a departure from available research on estimating electricity consumption. This study focuses on the disaggregate level of electricity consumption specifically in the different sectors in the economy. The main reason is that very little empirical work has been undertaken on electricity consumption modelling outside the aggregate level. To the best of our knowledge, no articles have been found dedicated to electricity consumption by the industrial, commercial, mining and agricultural sectors in Malaysia. According to Abid & Sebri (2012), the importance of the adoption disaggregate analysis allows to distinguish between the pattern of the different sectors towards electricity consumption. Analyzing the sectoral demand functions will provide the benefit of additional information that was veiled through aggregation (Madlener, Bernstein & Gonzalez, 2011). Therefore, this approach will help to identify sectors that are significantly electricity dependent and enable special characteristics of the specific sector to be taken into consideration for planning a more accurate energy policy.

Hence, this study aims to shed light on the modelling electricity consumption, namely the industrial, commercial, mining and agricultural sectors to present empirical evidence on the elasticity and causality in Malaysia. To provide a reliable sectoral electricity consumption model, the above mentioned variables such as sectoral GDP and real electricity price will be applied. The key contribution of this study is to provide some information on the responsiveness of electricity consumption toward the changes in economic performance and electricity price in sectoral level. Another contribution is to investigate any potential causal relationship between electricity consumption with economic performance and electricity price where the results would be useful for a recommendation of energy policies.

1.4 OBJECTIVES OF THE STUDY

From the problem statement discussed above, the objectives of this study are identified. These objectives are divided into general and specific objectives.

The general objective of this study is to estimate the relationship between electricity consumption, economic performance and the price of electricity in four sectors namely the industrial, commercial, mining and agricultural by using the panel data approach.

The specific objectives of this study are:

1. to examine the long run cointegration between electricity consumption, economic performance and the price of electricity

2. to examine the long run elasticity of economic performance and the price of electricity towards electricity consumption

3. to examine any potential causal relationship between electricity consumption with economic performance and the price of electricity

1.5 SIGNIFICANCE OF THE STUDY

The present study intends to contribute significantly to the existing literature by presenting a comprehensive approach of the issue of electricity consumption in Malaysia. The information of electricity consumption in the industrial, commercial, agricultural and mining sectors is essential to understand the magnitude of the sectors' sensitivity to change with respect to GDP and electricity price. Moreover, real electricity price is incorporated in this study to provide a more consistent result. The findings are important for researchers and academicians by providing a better knowledge of sectoral electricity demand to permit better regulatory decisions in order to facilitate economic efficiency. Apparently for the policy makers, it will be possible that the approach of this study could be useful as a guideline to facilitate the adoption of a more appropriate model for electricity demand management as well as restructuring the electricity sectors. Furthermore, the findings of this study will be helpful in the formulation of effective energy and pricing policies in order to encourage consumers towards the efficient use of energy for the future of sustainable energy and development.

1.6 SCOPE AND LIMITATIONS OF THE STUDY

This study focuses on the impact of economic performance and electricity price on electricity consumption in the different economic sectors in Malaysia. Based on annual data from the period 2002 to 2012, this study employs panel data analysis to examine the relationship between sectoral electricity consumption with GDP and electricity price as well as other control variables such as the number of electricity consumers, capital investment and employment. The analysis will be executed using econometric techniques such as the panel unit root test, the panel cointegration test, the panel FMOLS estimation and the panel Granger causality test.

The first limitation of this study is the data on electricity and economic variables across sector are available in shorter time periods. In some sectors, the data on electricity consumption is only available from 2006. Therefore, it is assumed that the growth rate of this set of data from 2002 and 2005 has not changed significantly. Due to the difference between the years, the values are estimated based on their growth rate over the future seven years from 2006 to 2012.

Furthermore, the data on electricity price or tariff imposed on each sector are heterogeneous and also differ according to three power utility companies, namely TNB, SESB and SEB. Thus, to incorporate this problem, this study applies an average electricity tariff. In order to measure the average electricity tariff, the tariff rates, based on the different sectors in the respective utility companies, are added. Finally, the total electricity tariff by each sector is divided by three.

1.7 ORGANIZATION OF THE STUDY

This study consists of five chapters. Chapter Two reviews the relevant theoretical and empirical literatures concerning the electricity consumption model. Chapter Three explains the methodology used in determining the sectoral electricity consumption model. Chapter Four discusses the empirical results of the analysis based on the panel unit root test, the panel cointegration test, the panel FMOLS estimation and the panel Granger causality test. Finally, Chapter Five provides the summary of the study and discusses the implications of the findings.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter consists of two major interrelated sections. Section 2.2 reviews the different economic theories relating to electricity consumption. Section 2.3 is concerned with empirical studies on the relationship between electricity consumption and economic performance, electricity price and other relevant variables that are comprehensively reviewed in Section 2.3.1, Section 2.3.2 and Section 2.3.4, respectively. Furthermore, estimation issues regarding electricity consumption have also been reviewed in Section 2.3.3.

2.2 THEORETICAL REVIEW

Electricity can be referred to as derived demand because electricity is a function of the types of electrical appliances that exist in a particular type of dwelling or building. In this context, electricity is derived along with other inputs for a factor of production resulting from the demand of other intermediate goods or services. Inglesi-Lotz & Blignaut (2011) stated that there were two approaches in dealing with electricity consumption based on the economic perspective. The first approach was from the supply side where electrical energy is used as an input for the production output of the sector. However, the results from the regression analysis were found to be insignificant and it was concluded that electricity consumption was not an appropriate factor to explain the output trends of the sectors. The second approach was from the demand side where consumers used electrical energy as a result of the output and prices. Based on this approach, it was suggested that electricity consumption from the demand side was appropriate in analyzing the electricity consumption model. This means that consumers' electricity consumption was a function of electricity price and the total output produced in each sector.

The rationale of behaviour of consumers on the demand of electricity is based on different theoretical foundations. A small number of theories have been proposed to explain the diverse cause of electricity demand in order to have a better understanding of the factors that influence the demand for electricity. Although the articles, such as Filippini (1999), Beenstock *et al.* (1999) and Alter & Syed (2011) cover a variety of theories, this review will focus on the seven most important factors that influence the demand for electricity, which emerge repeatly throughout the literature reviewed. These factors are price of electricity, income or GDP, price of substitute energy, population, weather, stock of electrical appliances and the number of consumers. To achieve the objective, this study will primarily focus on the application of price of electricity and GDP.

Generally, the consumption of energy is mainly determined by its own price. Cooper (2003), in his study on crude oil demand, has claimed that the price elasticity of demand for energy was important for policy makers to monitor the quantity of energy demand. He suggested that the price of elasticity was very low in the long and short run that was derived from a variety of econometric procedures and covered different periods. Meanwhile, Estrada & Fugleberg (1989) analyzed the price elasticity of natural gas and they argued that the fluctuation in natural gas price had a significant effect on consumers' change in their fuel demand.

On behalf of electricity consumption, the price of electricity or electrical tariff is commonly used to determine the quantity of electricity usage. According to the law of demand, the price of electricity is assumed to have an inverse relationship to the quantity demanded for electricity. Therefore, in the function of electricity consumption, electricity price plays an important component due to its greater influence on affecting the quantity of electricity consumed. The majority of the articles on electricity consumption analysis such as Polemis (2007), Inglesi (2010) and Sabir, Ahmad & Bashir, (2013), concluded that a higher electricity price would cause a substantial reduction in overall electricity consumption, while a falling in electricity price would increase the usage of electricity, *ceteris paribus*. For instance, when the price of electricity increases, it increases the total cost of production. In order to lessen the cost of production, a firm will reduce the purchase of electricity energy. As a result, the firm's demand for electricity will decrease.

Recent study outlined by Worthington (2010), who focused on commercial and industrial water demand, argued that the demand for energy did not only depend on the price of energy, but was also influenced by the sector performances. In general, the majority of economic articles on electricity consumption such as Inglesi-Lotz & Blignaut (2011), Alter & Syed (2011) and Javid & Qayyum (2014) have considered the relationship between electricity and the economic performance or income based on GDP. In particular, as economic development progresses, consumption and production patterns will change, thus resulting in changes in energy use patterns.

Most articles on electricity demand, such as Pouris (1987), Al-Faris (2002) and Ekpo, Chuku & Effiong (2011), have observed that an increase in GDP will lead to an increase in electricity demand. For instance, an increase in GDP will raise consumer wealth, thus consumers get an extra income to spend. Thereby, it raises more consumption for the quantity of goods and services. These structural changes in consumption result in changes in production. In other words, when the demand for goods increases, firms will raise the production and this will promote changes in electricity consumption. This means that more additional electricity is required in order to produce more output.

According to the sectoral or firm perspective, electricity is an essential input for the production process of goods and services, similar to labour and capital. As explained by Narayan, Smyth & Prasad (2007), in order to produce a unit of product, a firm needs an input factor in the form of electricity. Thus, electricity demand adds to the production function. Generally, the objective of the firm is to maximize profit or to minimize cost for a given level of outputs. For instance, the profit maximizing firm will choose both input and output with the sole goal of maximizing economic profits that refer to the difference between total revenue and total cost. Profit maximization is subject to a production function that generates a demand for a product as a function of the price of the product, the level of output, the proportion of inputs in production and the price of inputs. Several studies on industrial electricity demand, such as Lakhani & Bumb (1978) and Tishler (1983), applied the producer of profit maximization theory.

In comparison, cost minimization is an alternative way considering the behaviour of a profit maximizing firm that takes factor prices as given but can influence output prices. According to Medlock III, a firm purchases energy as an input to the production of its output and naturally attempts to do it in accordance with cost minimization (Evans & Hunt, 2009). Another study by Dias-Bandaranaike & Munasinghe (1983) used the cost minimization model on electricity consumption function. In this model, the authors considered production as a function of energy services, including the service of electricity and other kinds of energy as well as the service of other production factors such as labour and capital. Furthermore, electricity service was considered as a function of electricity consumption and the quality of electricity supply. The production cost subject to the production function constraint was minimized and electricity consumption of an individual firm was introduced as a function of the electricity supply quality, electricity price, price of substitute energy and the firm's value added.

Recently, Pourazam (2012) analyzed the demand behaviour of electricity consumption in different sectors in Iran. Based on the article by Baxter and Rees in 1968, he described the concept of cost minimization of production cost was subject to the production function constraint. In his study, he claimed that the production by the industrial and agricultural sectors was considered to be a function of electricity demand for an input together with other inputs in the production process. As a result, the basis of the quantity of electricity consumption was derived as a function of output of the industry, the price of electricity, the price of substitute fuel, labour and other exogenous factors. In addition, the author also included the stock of electrical appliances and technological progress as proxied by fixed capital to investigate the impact on the level of sectors' energy demand and consequently on the level of production. In other studies, some researchers, such as Worthington (2010) and Madlener, Bernstein & Gonzalez (2011), have also considered the cost minimization theory in their electricity consumption modelling.

In conclusion, from the brief review of the theories on electricity demand, it can be deduced that factors that cause the sectors' consumption of electricity generally can be categorized into demand side approach as a result of electricity price, output and other relevant factors.

2.3 EMPIRICAL REVIEW

The study on consumers' behaviour on electricity consumption is importantly needed in order to understand the causes that determine the change in the consumption of electricity. The importance of this study hinges on exploring two main factors such as economic performance and electricity price elasticity. This illustrates some information as how electricity consumption changes due to the impact of economic performance and electricity price. Furthermore, there is also a causal relationship between electricity consumption, economic performance and electricity price.

2.3.1 Relationship between Electricity Consumption and Economic Performance

Generally, GDP is the most commonly used variable as an indicator for measuring economic growth or national income in determining electricity consumption of the respective country. However, other electricity demand studies that specifically focus on sectoral levels also employed GDP as an indicator to represent the sector income or economic performance. For the purpose of this review, the terms of income, economic performance or economic growth are used interchangeably with GDP in order to explain its relationship with electricity consumption

In theory, the demand for normal goods should increase proportionately when there is an increase in income. As for energy, the measurement of income effects on consumption is important because energy bills often represent a lower proportion of income for higher income consumers (Arbues *et al.* 2003). In energy literature, the estimation of income elasticity for electricity consumption began with the study by Houthakker (1951) in the United Kingdom (UK). He was concerned with the response of consumers towards changes in income. The results revealed the stability in his electricity demand function and it indicated that electricity demand in the UK was sensitive to changes in economic performance.

Following his introductory study, research efforts on the estimation of income elasticity have become extensive and have raised the attention of analysts and researchers. For instance, several articles (Pouris,1987; Donatos & Mergos, 1991; Silk & Joutz, 1997; Al-Faris, 2002; De-Vita, Endersen & Hunt, 2006; Amarawickrama & Hunt, 2008; Dilaver & Hunt, 2011 and Selen & Aysegul, 2012) used national income to estimate the electricity consumption in their respective countries. Based on their investigations, the estimation of income elasticity was universally significant and indicated a positive sign towards the change in electricity consumption. However, the level of income elasticity showed varying outcomes.

Donatos & Mergos (1991) measured the determinants of Greek electricity consumption from 1961 to 1986. They found that the income elasticity was elastic at 1.56. In the same vein, Al-Faris (2002) found similar findings of electricity demand in the Gulf Cooperation Council (GCC) member states, namely Bahrain, Kuwait, Oman, Saudi Arabia and United Arab Emirates between 1970 and 1997. The outcomes indicated that the long run elasticity of income between GCC countries was very elastic, and varied from 1.65 to 5.39. Moreover, Amarawickrama & Hunt (2008) also found consistent results for electricity demand in Sri Lanka covering the period from 1970 to 2003. The income elasticity had a range of between 1.00 and 1.96.

Several researchers discovered that electricity consumption was actually less sensitive to changes in income in the long run. Pouris (1987) examined the influence of GDP on electricity consumption in South Africa over the period from 1950 to 1983. He revealed that the income elasticity was inelastic as estimated at 0.71. In another study, Ziramba (2008) also found consistent results regarding the inelasticity of income. Based on per capita studies over the period from 1978 to 2005, he concluded that electricity consumption of South Africa was driven by GDP as estimated at 0.31. Meanwhile, Silk & Joutz (1997) studied electricity demand of the United States and they concluded that the income elasticity was close to 0.5. Moreover, De Vita *et al.* (2006) conducted a study on the effect of GDP on electricity demand in Namibia from 1960 to 2002. In this study, they reached the same conclusion that electricity consumption was actually driven by income, where the elasticity was found to be inelastic at 0.59.

Recently, Dilaver & Hunt (2011) and Selen & Aysegul (2012) tried to investigate electricity consumption in Turkey as a function of GDP. Dilaver & Hunt (2011) estimated the income elasticity over the period from 1960 until 2008. The findings indicated that electricity consumption tended to be very inelastic due to the change in income as calculated to be 0.17. The results, reflecting the nature of the demand for electricity was similar to those reported by Selen & Aysegul (2012). The authors used different time periods from 1970 to 2009 and the estimation of income elasticity was found to be 0.92. By making the comparison, it can be concluded that electricity consumption in Turkey was less responsive to changes in GDP.

Based on the findings from previous articles, there were similarities between the positive responses of electricity consumption and the changes in income in the long run. However, the results also indicated that electricity consumption had shown different sensitivities to income changes in their respective countries. For example, De Vita *et al.* and Dilaver & Hunt (2011) found that the income elasticity was lower than unity in the long run, whereas the study of Donatos & Mergos (1991) and Al-Faris (2002) presented that income elasticity ranged from 1.56 to 5.39. This suggested that electricity demand was responsive to variations in income in the long run. Ekpo *et al.* (2011) claimed that income level, often used as a proxy for GDP was the most important determinant of electricity demand.

In causality analysis, a number of articles found a significant relationship between GDP and electricity consumption. These assessments of the causal relationship were valuable for an appraisal of conflicting policy objectives such as the trade-off between economic growth and energy conservation (Madlener *et al.* 2011). For instance, Shiu & Lam (2004) found unidirectional causality from electricity consumption to real GDP in China based on annual data from 1971 to 2000. From this finding, they suggested that the Chinese government should speed up the electricity infrastructure to overcome constraints on electricity consumption. Between 1950 and 2000, Altinay & Karagol (2005) concluded that electricity consumption was a leading indicator of the economic growth in Turkey. Recently, Chandran *et al.* (2010) investigated the relationship between electricity consumption and real GDP growth in Malaysia over the period from 1971 to 2003. The study found that causality flowed from electricity consumption to real GDP in the short run through which it was concluded that Malaysia was an energy dependent country.

In other studies, Wolde-Rufael (2006) and Yoo & Kwak (2010) focused on the causal relationship in several countries. For instance, Wolde-Rufael (2006) investigated the dynamic independence between electricity consumption and GDP in 17 African countries from 1971 to 2001. The results varied from country to country, where there was causality from electricity consumption to GDP for Nigeria, Ghana, Cameroon, Zambia, Senegal and Zimbabwe. However, negative causality was found between electricity consumption and GDP in Tunisia and it was concluded that the country only required less energy for the development of its economy. Likewise, Yoo & Kwak (2010) focused on South American economies for the period from 1975 to 2006. Interestingly, it was found that there was causality running from electricity consumption to GDP in Columbia, Ecuador, Brazil, Argentina and Chile.

Meanwhile, a number of studies found a causal relationship running from GDP to electricity consumption. For example, Ghosh (2002) studied the relationship based on electricity consumption per capita and GDP per capita in India from 1950 to 1997. The study found an absence of long run equilibrium among the variables but it was found that there was unidirectional causality running from economic growth to electricity consumption. The author concluded that electricity conservation policies can be initiated without deteriorating economic side effects. In a similar vein, Mozumder & Marathe (2007) also found that per capita GDP influenced per capita electricity consumption in Bangladesh between the period from 1971 and 1999.

Similar findings were also found by Wolde-Rufael (2006) for African countries such as Zimbabwe, Ghana, Cameroon, Zambia, Nigeria and Senegal. Moreover, a study by Chen, Kuo & Chen (2007) examined the relationship between electricity consumption and GDP in Asian developing countries such as Malaysia, Singapore, Thailand, Indonesia, Hong Kong, China, India, Korea, Taiwan and the Philippines. Based on panel data covering the period from 1971 to 2000, they confirmed that unidirectional causality running from GDP to electricity consumption. In another study, Yoo (2006) also investigated causality analysis in four ASEAN countries namely Malaysia, Indonesia, Thailand and the Philippines using annual data from 1971 to 2002. The tests, however, indicated a causal relationship from GDP to electricity consumption only in Indonesia and Thailand.

A third group of investigations have found a bidirectional relationship. This relationship meant that both electricity consumption and economic growth were affected each other. Yoo (2005) investigated the direction of causality between electricity consumption and GDP in Korea from 1970 to 2002. The results showed the existence of bidirectional causality between electricity consumption and economic growth. In another contribution, Yoo (2006) also found bidirectional causality in the two ASEAN countries of Malaysia and Singapore. On the other hand, Wolde-Rufael (2006) found bidirectional causality in Morocco, Egypt and Gabon. Meanwhile, investigations by Yoo & Kwak (2010) clarified the existence of bidirectional causality in Venezuela.

In Malaysia, Tang (2009) investigated the causal relationship between electricity consumption and GDP from 1970 to 2005. The results revealed that GDP was positively related to electricity consumption in the long run. It indicated that electricity consumption and GDP were influenced each other. Other contributions by Lean & Smyth (2010) utilized annual time series from the 1971 to 2006 period. The results showed bidirectional causality between GDP and electricity consumption. The authors suggested that Malaysia should adopt a dual strategy of increasing investment in electricity infrastructure and electricity conservation policies in order to avoid the negative effect of reducing electricity consumption in GDP.

Contrary to the above studies, some studies did not find any relationship between electricity consumption and GDP. For instance, Wolde-Rufael (2006) found no causality in any direction in African countries such as Kenya, Algeria and South Africa. The author suggested that electricity energy may not be an important factor in complementing other factors of production and may not be used extensively in the production of goods and services. Yoo & Kwak (2010) found no causal relationship in Peru.

The causality studies on respective countries yielded mixed results in terms of the direction between electricity consumption and GDP. According to Acaravci & Ozturk (2010), different directions of causality have their implications on the formulation of energy policies. They explained that if electricity has an important role in GDP, then policies encouraging a reduction in electricity usage will have an effect on a country's economic growth. When the GDP causes electricity consumption, then energy conservation policies can be designed with less effect on economic growth. Finally, if the results suggested that both electricity consumption and GDP are interrelated, then policy makers should take into account the feedback effect of GDP growth on electricity consumption by implementing regulations in order to reduce the consumption of electrical energy.

2.3.2 Relationship between Electricity Consumption and Electricity Price

In theory, electricity price elasticity can be measured by unit changes in electricity consumption with respect to unit changes in electricity price. However, there was a wide variation in the electricity price specifications reported in the literature. For instance, classical studies on electricity price elasticity such as Fisher & Keysen (1962) categorized the related works by residential and industry between 1946 and 1957. For electricity demand function, average revenue was used to represent electricity price. It was found that electricity price had little effect on long run electricity demand. The price elasticity was ranged from -0.22 to -0.99. In another study, Halvorsen (1975) used the same average revenue to address electricity demand in the United States (US), incorporating the use of pooled data of 48 states from 1961 to 1969. He concluded that electricity demand was responsive to change in electricity price as calculated from -1.09 to -1.14. Within the same country, Wilson (1971) and Anderson (1972) employed typical bills based on 500 kilowatt hours per month to represent electricity price in their cross section studies in 77 cities and 50 states. Both authors came up with the findings that electricity price elasticity ranged from -0.84 to -1.33.

Recent studies by Kamaludin (2013), Holtedahl & Joutz (2004), Inglesi (2010), Bekhet & Othman (2011) and Ivy-Yap & Bekhet (2014) estimated the demand for electricity focused in developing countries. For instance, Kamaludin (2013) studied the electricity consumption in 32 developing countries from the 1999 until 2004 period. He employed price of oil as a proxy for the price of electricity due to difficulties to get data information. He argued that electricity price was actually dependant on oil price and indicated that electricity price would increase when there was an increase in oil price. Therefore, the estimation coefficient of electricity price elasticity in developing countries was found to be inelastic at -0.036. However, the result was found to be biased because the price of oil could not explain the level of electricity consumption more precisely to measure consumers' response to a change in price. Therefore, Kamaludin (2013) suggested that the application of real electricity price would provide more accurate and appropriate results.

In another study, Holtedahl & Joutz (2004) employed the real electricity price to estimate the electricity demand in India over the period from 1959 to 1995. As a result, they found that the price elasticity in the long run was inelastic, as estimated at -0.16. Recently, Ekpo *et al.* (2011) used electricity price per capita to measure electricity consumption between 1979 and 2008. However, the model suggested that the price elasticity was found to be insignificant to explain the electricity usage in Nigeria.

In Malaysia, academic studies about electricity consumption are rare, with Bekhet & Othman (2011) and Ivy-Yap & Bekhet (2014) being among the main contributors. Bekhet & Othman (2011) examined rural and urban electricity consumption using annual data from 1980 until 2009. In these studies, they employed the CPI as a proxy for electricity price. The results showed that the electricity price elasticity was found to be insignificant as estimated at 0.59. This means that the price of electricity failed to explain the electricity demand both in rural and urban areas. In the same vein, Ivy-Yap & Bekhet (2014) examined the residential electricity consumption from 1978 to 2011. Similar to Bekhet & Othman (2011), they used the CPI as a proxy for electricity price. The results were also found to be insignificant where the price elasticity was estimated at -0.13. However, both findings were inaccurate because the CPI was used as a proxy for electricity price which could lead the results to be insignificant. According to Miller (1994), one of the main issues associated with the CPI was that it was actually a fixed quantity price index based on sample prices rather than relative quantities purchased by consumers.

In another study, Athukorala & Wilson (2009) estimated the short and long run electricity demand in Sri Lanka based on annual data from 1960 to 2007. In the study, they employed an average price of electricity as one of the main determinants. The long run and short run price elasticities were found to be inelastic as estimated at -0.62 and -0.16 respectively. Moreover, Inglesi (2010) also applied the same price specification to explain the electricity consumption in South Africa covering the period from 1980 to 2005. The result indicated that electricity demand was less responsive to changes in electricity price in the long run as estimated to be at -0.56. According to Helden, Leeflang & Sterken (1987), the average electricity price was the right indication and was statistically significant. They suggested that the average electricity price should be used in the electricity demand function.

For causality analysis, very small number of studies such as Asafu-Adjaye (2000), Athukorala & Wilson (2009) and Bekhet & Othman (2011) investigated the relationship between energy and electricity consumption together with its own price. For instance, Asafu-Adjaye (2000) investigated the relationship between energy consumption and energy prices in four Asian countries namely India, Indonesia, the Philippines and Thailand. He discovered that there was a significant long run relationship running from energy price to energy consumption in Indonesia and Thailand, but no relationship was discovered in India and the Philippines. Meanwhile, Athukorala & Wilson (2009) found bidirectional causality between electricity consumption and electricity price in Sri Lanka. In Malaysia, Bekhet & Othman (2011) discovered unidirectional causality running from electricity consumption to electricity price. They claimed that an increase in the consumption of electricity would cause inflation which would lead to a reduction in consumer purchasing power.

Based on the above reviews, all estimated electricity price parameters have the expected sign but there was no consensus regarding the magnitude of price elasticity towards the demand for electricity. The majority of the studies, such as Holtedahl & Joutz (2004), Athukorala & Wilson (2009) and Kamaludin (2013), concluded that electricity price had a negative relationship with electricity consumption in the long run. However, the estimated price elasticity lay within a wide range of between –1.33 and –0.036. On the other hand, there were mixed results in terms of causality relationship between energy, electricity and its own price.

2.3.3 Estimation Issues in Electricity Consumption

Despite the relevant studies on estimating electricity consumption, previous articles such as Al-Faris (2002), Inglesi (2010), Bekhet & Othman (2011), and Selen & Aysegul (2012) only focused on the aggregate level or total electricity consumption. This could contribute to the loss of information related to individual consumer behavior. Nevertheless, there was less empirical work that was concerned with the estimation of electricity consumption at sectoral levels within the industrial, commercial, mining and agricultural sectors. This was an important omission because these sectors accounted for a substantial amount of electricity that was used as key energy input in the production of goods and services. The demand for electricity in the sectoral level was subject to a few challenges including the reliability of electricity supply and the issue of the rising electricity price. Moreover, sectoral electricity consumption and its demand management are inherently complex, thus linking it with the possibilities of the potential to generate its own electricity to become more energy efficient.

For sectoral studies, the level of the sector economic performance, output and income were commonly used as explanatory variables to determine electricity demand. However, studies that specifically focus on sub-sectors in the individual sectors frequently employed the sector performance or output rather than income as accurate measures. Nevertheless, most studies, such as Alter & Syed (2011) and Javid & Qayyum (2014), employed GDP as an indicator to represent performance, output or income. In this review, there were studies focused on several sectors or individual sectors. Unfortunately, the empirical findings were found to be inconsistent across countries, sectors and different applications of econometric techniques.

For instance, Alter & Syed (2011) and Javid & Qayyum (2014) explored electricity consumption in aggregate and disaggregate levels namely in the industrial, commercial and agricultural sectors. Initially, Alter & Syed (2011) applied the Johansen (1988) cointegration technique based on an annual time period from 1970 to 2010. The long run elasticity in income showed a positive sign in all sectors including aggregate electricity consumption. Income elasticity in the industrial and agricultural sectors was found to be elastic, as calculated at 1.04 and 1.0 respectively. In the aggregate level and the commercial sector, income elasticity was inelastic as estimated at 0.25 and 0.51 respectively. In the same vein, Javid & Qayyum (2014) applied the Structural Time Series (STS) technique from the period 1970 to 2006. The results showed an expected sign in GDP for all sectors which confirmed the findings by Alter & Syed (2011). The coefficients were found to be elastic in the industrial sector and the aggregate level, both calculated at 1.29 and 1.89 respectively. Meanwhile, the commercial and agricultural sectors were found to be inelastic as estimated at 0.17 and 0.43 respectively.

Moreover, Inglesi-Lotz & Blignaut (2011) estimated the industrial, commercial, mining and agricultural sectors in South Africa for the period 1993 to 2006. In this study, they employed annual panel data for modelling the sectoral electricity consumption by using the sectoral economic performance and electricity price as explanatory variables. Based on the Seemingly Unrelated Regression (SUR) technique, the results showed that the sector performance was only significant in the industrial and commercial sectors as estimated at 0.71 and 0.76 respectively. However, the sectoral economic performance from two other sectors, including the mining and agricultural sectors, does not significantly affect their own electricity consumption. In this study, the SUR technique provided the advantage because it captured the variables in each sector separately, characterized by heterogeneity in electricity usage.

The price elasticity in sectoral electricity consumption, namely in the industrial, commercial and agricultural sectors was also investigated based on electricity price. For instance, Ghader, Azadeh & Mohammadzadeh (2006) focused on the industrial and agricultural sectors in Iran between the period from 1979 and 2003. In this study, they employed the Ordinary Least Square (OLS) technique to estimate the electricity price elasticity and the results were estimated ranging from -2.9 to -0.01. However, the method applied in achieving this objective was erroneous because the OLS estimation was not sufficient to prove the nature and the relationship between electricity consumption and electricity price. In South Africa, Inglesi-Lotz & Blignaut (2011) found that industrial electricity consumption was less responsive towards the change in electricity price as estimated at -0.86. However, it was claimed that electricity price was not significant to explain the electricity consumption in the commercial, mining and agricultural sectors.

Within the same vein, Alter & Syed (2011) discovered a negative relationship between electricity price and electricity consumption in Pakistan. They explained that the long run price electricity was below unity at the aggregate level and the industrial sector as calculated at -0.85 and -0.55 respectively. In the commercial and agricultural sectors, electricity price elasticity was greater than unity at -1.83 and -1.66 respectively. This affirmed that as the electricity price increased, the demand for electricity fell. Meanwhile, Javid & Qayyum (2014) found an opposite relationship where the coefficient of electricity price elasticity in the industrial and agricultural sectors was positive as estimated at 0.21 and 0.08, respectively. The result of negative electricity price elasticity was consistent only in the commercial sector, estimated at -0.26.

In addition, several researchers, such as Polemis (2007), Ghandoor & Samhouri (2009), Dilaver & Hunt (2010) and Sabir *et al.* (2013) dedicated their studies only to the individual sector. Initially, Polemis (2007) investigated the industrial sector based on an annual time period between 1970 and 2004 in Greece. He applied the Johansen (1988) cointegration technique to estimate the long run relationship between industrial electricity consumption and electricity price. The price elasticity was found to be inelastic as estimated at -0.85. This suggested that the industrial electricity consumption in Greece was less responsive to the changes in its own electricity price.

Moreover, Dilaver & Hunt (2010) examined the industries within the context of Turkey covering the period from 1960 until 2008. In this study, the measurement of electricity price was obtained from the actual average electricity tariff specifically in the industrial sector. Based on the STS technique, it was concluded that electricity price was found to be an important factor to determine the demand for electricity in the industrial sector as estimated at -0.16. A recent study by Sabir *et al.* (2013) examined the industrial electricity consumption function in Pakistan using annual data from 1976 to 2008 period. The result from the Johansen and Juselius (1990) cointegration test revealed that electricity price elasticity was highly significant as calculated to be at -0.28. Referring to the findings by Polemis (2007), Dilaver & Hunt (2010) and Sabir *et al.* (2013), it can be concluded that the industrial electricity demand had a negative relationship with its own electricity price. This meant that the firms in the industrial sector would try to reduce their consumption of electricity when they identified that the price of electricity had increased.

In another study, Ghandoor & Samhouri (2009) investigated the factors that were derived from industrial demand for electricity in Jordan from 1985 to 2004. They applied the OLS technique and found that the electricity price elasticity was found to be insignificant in the long run. However, this study was silent in terms of the elasticity and no relationship was established between industrial electricity demand and electricity price, which was important in founding a theoretical reasoning of the study. Therefore, the findings of this study were not appropriate for proper generalization as compared to that of other studies such as Polemis (2007), Dilaver & Hunt (2010) and Sabir *et al.* (2013).

Attention has also been paid to electricity consumption in the commercial sector. For instance, Zachariadis & Pashourtidou (2007) investigated the commercial electricity price in Cyprus based on annual data from 1960 to 2004. In this study, they applied the Johansen (1988) cointegration technique and the results indicated that electricity price elasticity was inelastic as measured at -0.29. This described that electricity was an important commodity to the commercial sector.

2.3.4 Relationship between Electricity Consumption and Other Variables

The demand for electricity commodity is not always explained by its own price and income, but it is also influenced by other potential factors that significantly affect electricity consumption. These factors could be from the population, number of customers, electrical appliances, substitute price of energy and weather depending on the nature of the electricity commodity. Recently, empirical studies, such as Donatos & Mergos (1991), Alter & Syed (2011) and Bekhet & Othman (2011) had considered other different explanatory variables to explain the aggregate level and sectoral electricity consumption. For instance, Ekpo *et al.* (2011) considered population as a determinant of electricity consumption in Nigeria. The results of the study revealed the positive elasticity in population as estimated at 0.89. This implied that a higher population would constitute a major driver for electricity demand in Nigeria. In another study, Bekhet & Othman (2011) discovered the positive relationship between population and electricity consumption especially in urban areas. The urban population indicated more sense in terms of electricity consumption rather than the rural population as estimated at 1.08 and 0.2 respectively. They claimed that the increase in the consumption of electricity by the urban population was due to higher exposure to stocks of electrical appliances and electrical transportation.

Meanwhile, Ghandoor & Samhouri (2009) and Ubani *et al.* (2013) analyzed employment in modelling the industrial electricity demand. According to Ghandoor & Samhouri (2009), employment referred to the number of employees that required additional electricity consumption, such as the demand for space lightning, air conditioning and heating. The result showed that employment was found to be insignificant to explain industrial electricity demand in Jordan. In Nigeria, Ubani *et al.* (2013) argued that employment would have an effect on the rate of purchase of electrical appliances which increased electricity consumption. The results showed that a unit change in employment level increased the consumption of electricity as calculated at 0.025.

Furthermore, several studies, such as Donatos & Mergos (1991), Egelioglu, Mohamad & Guven (2001) and Ghader *et al*. (2006), incorporated the number of consumers as one of the explanatory variables. For instance, Donatos & Mergos (1991) studied electricity consumption in Greece covering the period from 1961 to 1986. During the investigation period, it was found that the coefficient of the number of electricity consumers was significant and played a very important role in the expansion of electricity usage in Greece. Egelioglu *et al.* (2001) also confirmed that the number of electricity consumers was a proper determinant and showed a strong predictive in modelling the annual electricity consumption in Northern Cyprus. In Iran, Ghader *et al*. (2006) found that the elasticity for the number of electricity consumers in industrial and agricultural sectors showed a positive sign as estimated at 0.24 to 1.2 respectively.

In another study, Alter & Syed (2011) employed the number of electricity consumers to represent the quantity of firms that used electricity for the derivation of utility. The results of elasticity were found to be mixed. In the aggregate level and the commercial sector, the number of customers showed a positive sign as estimated at 0.07 and 0.62 respectively. Meanwhile, in the industrial and agricultural sectors, the number of consumers showed an opposite sign as both were estimated to be -1.71 and -0.93 respectively. This implied that electricity usage would increase in the aggregate level and the commercial sector but it would reduce in the industrial and agricultural sectors due to an increase in the number of consumers. In the same vein, Khan & Qayyum (2009) found evidence that the number of electricity consumers had a significant impact on the sectoral electricity demand in Pakistan from the period 1970 to 2006. The number of electricity consumers in the industrial and agricultural sectors indicated a positive sign as estimated at 2.42 and 2.21 respectively. However, none of the energy studies in Malaysia have investigated the impact of consumers either on the aggregate level and sectoral electricity consumption.

Furthermore, a small number of studies, such as Holtedahl & Joutz (2004), Alter & Syed (2011) and Pourazam (2012), applied electrical appliances in their electricity consumption modelling. According to Alter & Syed (2011), it was argued that the stock of electrical appliances was an important influencing factor to be considered in electricity consumption model. For instance, Holtedahl & Joutz (2004) used urbanization as a proxy to capture the effects of technological changes in the stock of electrical appliances. The results showed that urbanization was an important variable in the long run, where elasticity was estimated at 3.91. Meanwhile, Alter & Syed (2011) employed the value of imported electrical goods as a proxy for electrical appliances. This variable was used to investigate the usage of electrical goods and capital stock between the economic sectors in Pakistan. Thus, the results of electrical appliance elasticity was found to be significant and showed a positive sign in all sectors ranging from 0.23 to 1.69. This indicated that an increase in the usage of electrical appliances would further increase the consumption of electricity.

In Iran, Pourazam (2012) used fixed capital as a proxy for the stock of electrical appliances of the commercial sector and for the technology of the industrial and agricultural machinery. The author claimed that fixed capital was considered to explain the total investment of buildings and machinery in the commercial, industrial, public and agricultural sectors. Thus, it required the provision of more electrical appliances and equipment. The reason for such a relationship was that higher fixed capital in the form of appliances and machinery represented increasing investments in new electrical appliances and machinery. However, fixed capital was found to be insignificant to explain sectoral electricity demand. In Malaysia, none of the studies have tested the influence of the stock of electrical appliances on sectoral electricity demand.

Other studies, such as Narayan & Smyth (2005), Bekhet & Othman (2011), Jamil & Ahmad (2011) and Pourazam (2012) also considered different forms of energy or fuel as an alternative to electricity. This assumed that natural gas, oil, and diesel could be used as substitute forms of energy to electricity. However, this was not easily validated because electricity has unique characteristics. According to Pouris (1987), electricity was the cleanest of all fuels and it was versatile and easily transferable. Thus, it was impossible or difficult for other fossil fuel processes to compete. For instance, Narayan & Smyth (2005) employed natural gas as a substitute form of energy for electricity consumption in Australia. It was found that natural gas was not a perfect substitute for electricity. Similarly, Bekhet & Othman (2011) found that natural gas price elasticity was insignificant to explain the electricity consumption in rural and urban areas in Malaysia. Moreover, Jamil & Ahmad (2011) suggested that electricity was not a perfect substitute for other forms of energy during his study on the aggregate level and the sectoral electricity demand in Pakistan. Pourazam (2012) also found that substitute forms of energy, such as diesel, gas and fuel oil, had no substitution relationship with sectoral electricity demand. These results highlighted that the elasticity of substitute energy was either inelastic or insignificant. Therefore, it can be concluded that the substitute price of energy is not appropriate to explain electricity consumption.

A considerable proportion of electricity demand also comes from the usage of air conditioning and heating in the summer and winter. Thus, it has gained the interest of researchers to investigate the impact of temperature on electricity consumption. Dergiades & Tsoulfidis (2008) and Silk & Joutz (1997) estimated electricity demand in the U.S. from 1965 to 2006 and 1953 to 1993 respectively. The results showed the coefficients of weather conditions to be statistically significant in the long run the in the U.S. Conversely, Narayan & Smyth (2005) found that electricity demand in Australia was sensitive to weather conditions in the long run. Nonetheless, this variable may not have been applicable in explaining electricity consumption in Malaysia. The main reason was that Malaysia, as a tropical country experienced constant temperature throughout the year. According to Ivy-Yap &Bekhet (2014), any variation in the usage of electricity in Malaysia was not coming from weather conditions because the temperature always constant all the time.

2.4 CONCLUSION

The vast majority of studies indicate that electricity consumption depends on income or GDP and its own electricity price. In general, the change in electricity consumption is consistent with a positive and negative relationship between GDP and electricity price. However, the findings on the level of income elasticity and price elasticity are still inconclusive. Other factors that could influence sectoral electricity consumption include the number of electricity consumers, employment and the stock of electrical appliances to be considered. Despite focusing on the aggregate level, this study tends to give attention to sectoral levels by investigating electricity consumption behaviour in the industrial, commercial, mining and agricultural sectors. The model of sectoral electricity consumption will be discussed in Chapter Three.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This chapter provides the econometric methods and procedures to analyze the sectoral electricity consumption in Malaysia. It incorporates five fundamental sections. These include the theoretical framework, model specification, justification of the relevant variables, data collection as well as the discussion of the econometric method analysis.

3.2 THEORETICAL FRAMEWORK

Theoretically, the demand for electricity is derived demand that comes from the demand for lighting, heating, cooling and others. In the study by Pourazam (2012), electricity demand by the different sectors, such as the industrial and agricultural sectors are modelled as the outcome of a cost minimization theory that is used by a firm in the production process. As a result, production by these sectors is considered to be a function of electricity demand input and demand input of labour, capital and other inputs. Following the work by Pourazam (2012), the behavioural equation of a firm's electricity demand function is constructed from the production function as follows:

$$Q = f(D_E, D_S, L, K) \tag{3.1}$$

Where Q is the level of output and D_e, D_s, L and K are the quantity of electricity, being substitute energy, labour and capital respectively. Minimization of production cost subject to the constraint of the production function presents the electricity demand of the firm (D_e) as follows:

$$D_e = f(Q, P_e, P_s, P_l, P_K) \tag{3.2}$$

where P_e, P_s, P_l and P_K are the price of electricity, being the substitute fuel, labour and capital respectively.

For m consumers, the power demand is the sum of the electricity consumption of all firms in the industry:

$$Q_e = \sum_{i=1}^{m} D_e$$

where Q_e is the electricity demand of the industry. Therefore

$$Q_e = f(Q', P'_e, P'_s, P'_l, P'_K) \tag{3.3}$$

where Q' is the total output and P'_e, P'_s, P'_l and P'_K are the average price of D_e, D_s, L and K respectively for the whole industry.

Let the functional form of demand assume constant elasticity, then:

$$Q_e = f(Q'^{\mu}, P_e'^{\alpha}, P_s'^{\beta}, P_l'^{\delta}, P_K'^{\tau}) \tag{3.4}$$

By taking the log transformation from both sides of Equation (3.4), the electricity demand function can be given by:

$$q_e = f(p \quad + \alpha \quad {}_e + \beta \quad {}_s + \delta \quad {}_l + \tau \quad {}_K) \tag{3.5}$$

where the lowercase letters display the log value of the variables. As shown in Equation (3.5), the parameters α, β, δ and τ are estimates of the elasticity. Based on the theoretical and empirical reviews, this study considers p to represent income or output. Meanwhile, α represents the price of electricity, β indicates the price of substitute fuel, δ indicates the price of labour, and τ represents the price of capital. Note that the price of substitute energy is not included in this study since it does not significantly explain electricity demand according to Bekhet and Othman (2011) and Jamil and Ahmad (2011). Moreover, due to the lack of data for p_l, total employment will be considered in this series.

3.3 THE MODEL

Since the determinants of electricity consumption vary across different countries, several studies have developed a diverse form of electricity consumption models. The econometric model used in this study was developed based on the cost minimization theory, but the model has been modified to accommodate other independent variables that influence the demand for electricity. Specifically, studies on sectoral electricity consumption commonly employ GDP and electricity price as important elements in electricity consumption model. To adapt the sectoral electricity demand model in Malaysia, other factors such as the number of electricity consumers, employment and capital investment are also being considered as control variables. Several articles (Donatos & Mergos, 1991; Egelioglu *et al.*, 2001; Ghader *et al*., 2006; Polemis, 2007; Athukorala & Wilson, 2009; Ghandoor & Samhouri, 2009; Khan & Qayyum, 2009; Dilaver & Hunt, 2010; Inglesi, 2010; Alter & Syed, 2011; Inglesi-Lotz & Blignaut, 2011; Abbas & Choudhury, 2013; Sabir *et al.*, 2013; Ubani *et al.*, 2013; Javid & Qayyum, 2014; and Ivy-Yap & Bekhet, 2014) also applied similar variables as mentioned in their electricity consumption analyses.

Therefore, this study will pool cross-section and time series data to examine the relationship between electricity consumption, GDP, the price of electricity, the number of electricity consumers, employment and capital investment. The function of electricity consumption can be written in the following equation:

$$EC = f\,(GDP, PE, CONS, EMP, CI) \tag{3.6}$$

where EC = Electricity consumption

GDP = Gross domestic product

PE = Price of electricity

$CONS$ = Number of electricity consumers

EMP = Employment

CI = Capital investment

Equation (3.6) shows that EC is the dependent variable and other variables are the independent variables which are expected to influence the EC. Based on the EC functions, the econometrical can be finally specified model as follows:

$$E_{ti} = \beta_1 + \beta_2 G_{ti} + \beta_3 P_{ti} + \beta_4 C_{ti} + \beta_5 E_{it} + \beta_6 C_{ti} + \varepsilon_{ti} \quad (3.7)$$

Where β_1 is a constant term, β_2 to β_6 are estimated parameters of explanatory variables, E_{ti} is electricity consumption at time t in sector i, G_{ti} is gross domestic product at time t in sector i, P_{ti} is the price of electricity at time t in sector i, C_{ti} is the number of electricity consumers at time t in sector i, E_{ti} is employment at time t in sector i, C_{ti} is capital investment at time t in sector i and ε_{ti} is an error term.

Following the specification by Pourazam (2012) as well as Alter & Syed (2011) and Madlener *et al.* (2011), the model in Equation (3.7) will be modified by using a double logarithmic linear form to give a direct estimate of the elasticity coefficient of the dependent variable with respect to the given independent variables:

$$ln_{ti} = \beta_1 + \beta_2 ln_{ti} + \beta_3 ln_{ti} + \beta_4 ln_{ti} + \beta_5 ln_{ti} + \beta_6 ln_{ti} + \varepsilon_{ti} \quad (3.8)$$

3.4 JUSTIFICATION OF VARIABLES

In this section, a detailed description and measurement of the various variables would be explained. The dependant of this study is EC. On the other hand, the explanatory variables for both models are GDP, PE, CONS, EMP and CI. A detailed description and measurement is provided below:

3.4.1 Electricity Consumption

Electricity consumption can be defined as the use of the final energy demand supplied to the final consumers. It does not include an own use by the power sectors as well as transmission, distribution and transformation losses (Worldbank, 2014). Data on electricity consumption are mostly used by previous studies in electricity demand analyses such as Alter & Syed (2011), Sabir *et al.* (2013), Javid & Qayyum (2014) and Ivy-Yap & Bekhet (2014). In this study, electricity consumption is a dependent variable and is consumed by four sectors in the economy namely the industrial, commercial, mining and agricultural sectors. It can be measured in total units of electricity sold in gigawatts per hour (GWh).

3.4.2 Gross Domestic Product

Gross Domestic Product is regarded as a key explanatory variable in this study. It measures the monetary value of final goods and services produced by factors of production within a given period of time. Generally, the electricity demand of each economic sector is driven by the level of economic performance of the sector. Growth in GDP specifies an increase in production activity which plays the major factor influencing electricity consumption. For example, an increase in industrial output contributes to GDP growth and is the key income driver for the industrial sector. As economic performance or income measures, GDP is used by previous studies such as Polemis (2007), Dilaver & Hunt (2010), Inglesi-Lotz & Blignaut (2011) and Abbas & Choudhury (2013). The relationship between GDP and electricity consumption is expected to be positive because an increase in GDP leads to an increase in production, therefore increasing the demand for electricity. In this study, the GDP of each sector is obtained as a share of the country's total GDP. The data on GDP is measured in constant prices (2000) in RM million.

3.4.3 Price of electricity

The price of electricity is an imperative variable in the function of electricity demand. It has an inverse relationship with the quantity demand for electricity. In Malaysia, homogenous electricity price or tariff does not prevail in all sectors. For example, the industrial sector has the lowest electricity tariff while on the other hand the agricultural sector has a high tariff. Therefore, this study considers the average electricity price for the industrial, commercial, mining and agricultural sectors. The average electricity price was used by prior studies such as Athukorala & Wilson (2009) and Inglesi (2010). Typically, it has a negative relationship with electricity consumption. The data on the average electricity price is measured in sen per kilowatt hour (sen/kWh).

3.4.4 Number of Electricity Consumers

Consumers mean any entity consuming electricity supply from utility company supply lines at any one point of supply. If an entity takes supply at more than one point, such an entity shall be deemed to be a separate consumer for each point of supply. The number of electricity consumers refers to the total consumers in the industrial, commercial, mining and agricultural sectors that consume electricity for the derivation of utility. This data was used by previous studies such as Donatos &

Mergos (1991), Egelioglu *et al.* (2001), Ghader *et al*. (2006), Khan & Qayyum (2009) and Alter & Syed (2011). The relationship is expected to be positive as an increase in the number of electricity consumers, means a large number of electricity units will be needed. In this study, the number of electricity consumers is used as a control variable and measured in million numbers for each sector.

3.4.5 Employment

Employment refers to the position or status of an employed person within the establishment or organization for which the person worked. In this study, employment is considered as a reflection to the demographic feature of population in the relevant economic sector. Employment is related to the number of employees that are linked to the floor area that require additional electricity in the form of lighting, air conditioning and heating. Therefore, data employment is applied in this study and was previously used by Ghandoor & Samhouri (2009) and Ubani *et al.* (2013). These variables are expected to be positively related with electricity consumption. An increase in employment could lead to the enhancing electricity consumption levels, and vice versa. Therefore, it is relevant to study the relationship between the amount of electricity used and the total number of workers by sector in the economy. In this study, employment is used as a control variable and measured in million persons.

3.4.6 Capital Investment

The stock of electrical appliances is considered in the electricity demand function because it is expected to have an impact on sectoral electricity consumers. This data was used by Alter & Syed (2011) and Pourazam (2012). In this study, capital investment is used as a proxy for electrical appliances and technological progress. Therefore, more fixed capital investment on the new building construction will provide more space and floor areas, thus requiring the provision of more electrical appliances and equipment, including ICT. As a result, a larger consumption of electricity will be needed. At the same time, investment in the technology embedded in such buildings and machines that save energy or optimize electricity consumption could affect the usage of electricity. Thereby, it is expected to reduce the overall electricity consumption. The data on capital investment is obtained from Malaysia's gross fixed capital formation. It will be used as a control variable in the electricity consumption model and measured in RM million.

3.5 DATA

Secondary data are utilized in this study based on a balance panel consisting of the annual data for 11 years, from the period of 2002 until 2012. The data are gathered and verified from various sources. For example, data on electricity consumption and the number of consumers are retrieved from the Malaysia Energy Information Hub, the Energy Commission of Malaysia website. Data on electricity price is collected from annual publications namely the Electric Supply Industry in Malaysia and the National Energy Balance by Energy Commission of Malaysia. Additional data on GDP, employment and capital investment are obtained from the Ministry of Finance website, the Economic Planning Unit website, the Department of Statistics, Malaysia website and the World Bank website.

3.6 METHOD OF ANALYSIS

To test the relationship between electricity consumption and its determinants while avoiding any spurious correlation, the empirical analysis of the electricity consumption function follows four steps. First, the panel unit root tests proposed by Levin, Lin and Chu (2002) will be employed to test for stationary in all the variables. Second, the panel unit cointegration approach developed by Pedroni (1999 & 2004) will be applied to test for the long run cointegrating relationship between the variables. Third, if a long run relationship exists, the panel Fully Modified OLS (FMOLS) developed by Pedroni (2000) will be used to estimate the elasticity of long run cointegration vectors. A long run relationship indicates that there must be direction of causality. For that, the panel Granger causality test will be used to examine the potential causal relationship in at least one direction.

3.6.1 Panel Unit Root Test

To overcome the low power of unit root test applied to an individual time series due to a shorter data period, the panel unit root test will be applied. According to Ramirez & Sharma (2008), the panel unit root tests will increase the power of unit root tests because the information in time series is enhanced by its contents of cross section data and lead to statistics with normal distribution in the limit. In this study, Levin, Lin and Chu (LLC) statistics will be employed to represent the common unit root test process. The LLC proposes a panel based Augmented Dickey-Fuller (ADF) test with a panel setting and it requires coefficients of autoregressive term ρ_1 to be homogenous across all individuals *i*. There is a three steps procedure to implement the test as follows:

The first step is to separate the Augmented Dickey–Fuller (ADF) regression for each individual series in the panel:

$$\Delta y_{ti} = \rho_i y_{i,t-1} + \sum_{L=1}^{\rho_i} \theta_{ti} \, \Delta y_{i\,t-L} + \propto_m \; d_m \; + \varepsilon_{ti} \tag{3.9}$$

where y_{ti} is the series of sector i in the panel over period t, ρ_i is the lag order, d_m is used to specify the vector of deterministic variables, $\propto_m$ is the corresponding vector of coefficients for model m = 1,2,3. For given *T* (time), select a maximum lag order ρ_m and then use $\hat{\theta}_{iL}$ to determine if a smaller lag order is preferred. Under the null hypothesis, θ_{iL} is zero when both $\rho_i = 0$ and $\rho_i \leq 0$. Once ρ_i is determined, orthogonalized residuals are obtained from two auxiliary regressions:

i. Δy_{ti} *on* Δy_{ti-L} $(L = 1, \dots, \rho_i)$ and d_m to get residuals $\tilde{e}_{it}$ and
ii. $y_{i,t-1}$ *on* Δy_{ti-L} $(L = 1, \dots, \rho_i)$ and d_m to get residuals $\tilde{v}_{it-1}$.

To control different variances across individuals, the residuals $\tilde{e}_{it}$ and $\tilde{v}_{it-1}$ must be standardized by performing:

$$\tilde{e}_{it} = \frac{\tilde{e}_i}{\hat{\sigma}_{\varepsilon i}} \text{ and } \tilde{v}_{it-1} = \frac{\tilde{v}_i}{\hat{\sigma}_{\varepsilon i}} \tag{3.10}$$

where $\hat{\sigma}_{\varepsilon i}$ is the standard error from each ADF regression, for i= 1,…., N.

Second step is to estimate the ratio of long run to short run standard deviations. The long run variance can be estimated as follows:

$$\hat{\sigma}_y^2 = \frac{1}{T-1}\sum_{t=2}^{T}\Delta y_{it}^2 + 2\sum_{L=1}^{\bar{K}} w_{\bar{K}L}\left[\frac{1}{T-1}\sum_{t=2+L}^{T}\Delta y_{it}\,\Delta y_{i,t-L}\right] \tag{3.11}$$

where $\bar{K}$ is a truncation lag parameter and must be obtained to ensure the consistency of $\hat{\sigma}_y^2$. For a Bartlett Kernel, $w_{\bar{K}L} = 1 - (\frac{L}{\bar{K}+1})$. For each individual *i*, the ratio of a long run standard deviation to the innovation standard deviation is defined as $\hat{s}_i = \frac{\hat{\sigma}_y}{\hat{\sigma}_{\varepsilon i}}$ and the average standard deviation estimator is denoted by $\hat{S}_N = \frac{1}{N}\sum_{i=1}^{N}\hat{s}_i$.

In the third step, the pooled OLS regression is run to estimate $\tilde{e}_{it} = \rho\tilde{v}_{it-1} + \tilde{\varepsilon}_{it}$. Then, the t-statistic, which is based on $\hat{\rho} = 0$, is calculated by:

$$t_\rho = \frac{\hat{\rho}}{\hat{\sigma}(\hat{\rho})} \tag{3.12}$$

where

$$\hat{\rho} = \sum_{i=1}^{N}\sum_{t=2+p_i}^{T_i}\tilde{v}_{i,t-1},\tilde{e}_{i,t} \,/\, \sum_{i=1}^{N}\sum_{t=2+p_i}^{T_i}\tilde{v}_{i,t-1}^2$$

$$\hat{\sigma}(\hat{\rho}) = \hat{\sigma}_{\tilde{\varepsilon}}^2 / \left[\sum_{i=1}^{N}\sum_{t=2+p_i}^{T_i}\tilde{v}_{i,t-1}^2\right]^{1/2}$$

$$\hat{\sigma}_{\tilde{\varepsilon}}^2 = [\frac{1}{N\tilde{T}}\sum_{i=1}^{N}\sum_{t=2+p_i}^{T_i}(\tilde{e}_{it} - \hat{\rho}\,\tilde{v}_{i,t-1})^2]$$

Under LLC test, the null hypothesis is H_0: $\rho = 0$ when there is a unit root across the cross-sections, whereas the hypothesis alternate is H_1: $\rho < 0$ when it contains no unit root. The null hypothesis is rejected if the *t*-statistic is lower than the relevant critical value or the probability of the *t*-statistic is lower than any significant level.

3.6.2 Panel Cointegration Test

After the panel series are found to be integrated at the same order at first difference, the next step is to test whether EC and the independent variables are cointegrated or whether there is the existence of stable long term relationship. Hence, the sectoral electricity demand relationship will be examined using the panel cointegration approach suggested by Pedroni (1999 & 2004). This procedure allows consistent and efficient estimation of the parameters in relatively small samples and also control for potential endogeneity of the regressors and serial correlation. In this study, panel cointegration tests proposed by Pedroni (1999) will be applied since he determines the suitability of the tests to be used in calculating the residuals from a cointegration regression after normalizing the panel statistics with correction terms.

These procedures make use of an estimated residual from the hypothesized long run regression of the following form:

$$y_{ti} = \alpha_i t + \beta_{1i} x_{1ti} + \beta_{2i} x_{2ti} + \cdots + \beta_M x_M + e_{ti} \quad (3.13)$$

for $t = 1, \ldots, T; i = 1, \ldots, N; m = 1, \ldots, M$

where *T* is the number of observations over time, *N* denotes the number of individual members of the panel and *M* is the number of independent variables. The parameter

u_i is the sector specific fixed effects that vary across individual cross sectoral units whereas $e_{i,t}$ is the error term, which is interpreted as a deviation from the long run equilibrium. The sector specific slope coefficients β_{1i}…..β_{M} are the long run elasticity to be estimated. Therefore, this specification allows for the cointegrating vectors to vary across the single sectors of the panel.

According to Abdullah, Bakar & Hassan (2014), they stated that Pedroni (1999 & 2004) provided two types of statistics including the heterogeneous panel and the heterogeneous group mean panel to test for panel cointegration. The first type of three statistics $Z_{\hat{v}\,N,T}$, $Z_{\hat{\rho}\,N,T-1}$, and $Z_{t\,N,T}$ are within the dimension approach which pools the residuals across the panel. The statistics referred to are as follows:

$$Z_{\hat{v}\,N,T} = T^2 N^{3/2} \left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{1\ i}^{-2}\ \hat{e}_{i,t-1}^{2}\right]^{-1} \tag{3.14}$$

$$Z_{\hat{\rho}\,N,T-1} = T\sqrt{N}\left[\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{1\ i}^{-2}\ \hat{e}_{i,t-1}^{2}\right]^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{1\ i}^{-2}\left(\hat{e}_{i,t-1}\Delta\hat{e}_{i,t} - \hat{\lambda}_i\right) \tag{3.15}$$

$$Z_{t\,N,T} = \left[\tilde{\sigma}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{1\ i}^{-2}\ \hat{e}_{i,t-1}^{2}\right]^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{1\ i}^{-2}\left(\hat{e}_{i,t-1}\Delta\hat{e}_{i,t} - \hat{\lambda}_i\right) \tag{3.16}$$

where $\hat{e}_{i,t-1}$ is the residual vector of the OLS estimation of Equation (3.13), while the other terms are properly defined by Pedroni.

The second type of statistics $\tilde{Z}_{\hat{\rho}\,N,T-1}$ and $\tilde{Z}_{t\,N,T}$ are based on the between dimension approach which averages the residuals for each panel. These statistics compute the group mean of the individual conventional time series statistics. They allow for a heterogeneous autocorrelation parameter across members. The statistics referred to are as follows:

$$\tilde{Z}_{\hat{\rho}\, N,T-1} = \sum_{i=1}^{N}\left[\sum_{t=1}^{T} \hat{e}_{it-1}^{2} \right]^{-1} \sum_{t=1}^{T}(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_{i}) \tag{3.17}$$

$$\tilde{Z}_{t\, N,T} = \sum_{i=1}^{N}\left[\tilde{\sigma}^{2} \sum_{t=1}^{T} \hat{e}_{it-1}^{2} \right]^{-1/2} \sum_{t=1}^{T}(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_{i}) \tag{3.18}$$

Pedroni indicated that these statistics were asymptotically normally distributed in each of those five statistics which can be expressed in the following form:

$$\frac{\varkappa\ \ ,_{T} - \mu\sqrt{N}}{\sqrt{v}} \Rightarrow N\,(0,1) \tag{3.19}$$

where $\varkappa\ \ ,T$ is the appropriately standardized form of the test statistics, μ and v are the expected mean and variance of the corresponding statistics. They are tabulated in Table 2 in Pedroni (1999). The null hypothesis of no cointegration for the panel cointegration test is the same for each statistic, H_0: $\gamma_i < 1$.

The alternative hypothesis for within the dimension approach is H_1: $\gamma_i = 1$, while for the between dimension approach is H_1: $\gamma_i < 1$. The panel *v* statistics is a one-sided test and diverges to positive infinity. Thus, large positive values reject the null hypothesis of no cointegration. The remaining six statistics diverge to negative infinitely. This means large negative values reject the null of no cointegration.

3.6.3 Panel Fully Modified OLS Estimation

Once the explanatory variables are cointegrated in the long run, then the model is estimated by adopting panel FMOLS techniques developed by Pedroni (2000). The purpose of FMOLS is to obtain long run cointegration relationship of the sectoral electricity consumption model. This technique is used for estimating the cointegration vector in the dynamic panel data that allows considerable heterogeneity across individual sectors of the panel. The advantage of using this technique is that the group means estimator is behaving reasonably well even in a relatively small sample under a variety of scenarios (Pedroni, 2000). Furthermore, *t*-statistics for the group mean panel FMOLS offers a more flexible alternative hypothesis than pooled FMOLS. This is because group mean panel FMOLS are based on the between dimension as opposed to the within dimension in the panel. Therefore, it calculates the cointegrating vectors for a common value under the null hypothesis. Meanwhile, under the alternative hypothesis the values for the cointegrating vectors are allowed to vary across groups.

In a study by Choong, Chye & Lau, (2011), it was stated that Pedroni (2000) expressed the estimation of the cointegrated panel data as follows:

$$Y_{it} = \alpha_i + \beta X_{it} + \mu_{it} \quad \text{and} \quad X_{it} = X_{it-1} + e_{it} \tag{3.20}$$

where, i = 1,2…, N sectors over the time period of t = 1,2…, M. Additionally, $Z_{it} = (Y_{it}, X_{it})' \sim I(1)$ and $\zeta_{it} = (\mu_{it}, e_{it})' \sim I(0)$ with covariance matrix of $\Omega_i = \Omega_i^0 + \Gamma_i + \Gamma_i'$ where Ω_i^0 is the contemporaneous covariance, Γ_i is the weighted sum of auto-covariances while $\Omega_i = L_i L_i'$ in which L_i is the lower triangular decomposition of Ω_i. The panel FMOLS estimator for coefficient β is given as:

$$\beta_F^* = N^{-1} \sum_{i=1}^{N} (\sum_{t=1}^{T} (X_{it} - \bar{X}_{it})^2)^{-1} (\sum_{t=1}^{T} (X_{it} - \bar{X}_{it}) y_{it}^* - T\hat{\gamma}_i) \tag{3.21}$$

where

$$y_{it}^* = (y_{it} - \bar{y}_i) - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} \Delta X_{it} \quad \text{and} \quad \hat{\gamma}_i = \hat{\Gamma}_{21i} + \hat{\Omega}_{21i}^{0} - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} (\hat{\Gamma}_{22i} + \hat{\Omega}_{22i}^{0})$$

Likewise, the associated t-statistic for the estimator can be generated as:

$$t_{\beta_F^*} = N^{-1/2} \sum_{i=1}^{N} t_{\beta_F^*, i} \text{, where}$$

$$t_{\beta_F^*, i} = (\beta_{F,i}^* - \beta_0)(\hat{\Omega}_{11i}^{-1} \sum_{t=1}^{t} (X_{it} - X_i)^2)^{1/2}$$

In this study, the FMOLS estimation results will be reported into the panel individual sectors and the panel group mean statistic of FMOLS estimators.

3.6.4 Panel Granger Causality Test

The panel cointegration technique suggests that a long run relationship may exist among the variables. Eagle and Granger (1987) and Granger (1988) implied that there could be Granger causality in at least one direction if two variables are cointegrated. To achieve the objective, an investigation on the causality relationship focused on electricity consumption, economic growth which represents GDP and electricity price. Referring to Section 2.3.1 and 2.3.2, the relationship among the variables, especially between electricity consumption and economic growth, has received much attention in past literature but the direction of causality is still unclear. Therefore, this analysis will help to identify the direction of a causal relationship in the case of Malaysia.

This study employed the panel data causality testing to perform the analysis between the single variables. The standard procedure to compute the Granger causality is by running bivariate regressions in a panel context. In general, the bivariate regressions take the form:

$$y_{it} = \alpha_{0i} + \alpha_{1i} y_{it-1} + \cdots + \alpha_{1i} y_{it-1} + \beta_{1i} x_{it-1} + \cdots + \beta_{1i} x_{it-1} + \varepsilon_{it} \tag{3.22}$$

$$x_{it} = \alpha_{0i} + \alpha_{1i} x_{it-1} + \cdots + \alpha_{1i} x_{it-1} + \beta_{1i} y_{it-1} + \cdots + \beta_{1i} y_{it-1} + \varepsilon_{it} \tag{3.23}$$

where *t* denotes the time period dimension of the panel and *i* denotes the cross sectional dimension.

Granger causality tests are used as a standard method for measuring the causal relationship between two variables. For instance, if variable x_{it} causes variable y_{it}, changes in x_{it} should come before any changes in y_{it}. It can be concluded that x_{it} Granger causes y_{it} when the history or lagged values of x_{it} in a significant manner improve the anticipation of y_{it} in a regression of y_{it} on another variable set (with y_{it} own past values). The other way round, y_{it} is said to Granger cause x_{it} if changes in

y_{t} comes before changes in the variable x_{t} (Gujarati, 2003). This test will only be valid if the variables are stationary or *I*(0). Therefore, it is important to run integration tests on each of the variables prior to the Granger causality tests.

3.7 CONCLUSION

The econometric procedure in this chapter was explained systematically in order to get the results from the panel cointegration, panel FMOLS and panel Granger causality tests on the sectoral electricity consumption in Malaysia. The results and analysis of this study will be discussed in Chapter Four in order to achieve the objectives of the study.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the empirical results of the sectoral electricity consumption model based on the panel data series for the period 2002 to 2012. In the beginning, the descriptive statistics and correlation analysis will be discussed first. This will be followed by the discussion of the analysis of the section based on the three econometric techniques such as the panel cointegration test, the panel FMOLS estimation and the panel Granger causality test.

4.2 DESCRIPTIVE STATISTICS

In the initial summary of the data, a descriptive analysis was conducted to describe the general situation of electricity variables such as electricity consumption, the price of electricity and the number of electricity consumers, as well as macroeconomic variables such as GDP, employment and capital investment. Descriptive statistics results as depicted in Table 4.1 report the mean, standard deviation, minimum and maximum values of all variables. The results indicate that the number of electricity consumers has the largest difference between the minimum value and the maximum value, as estimated between 2.565 and 14.214 respectively. Therefore, this variable has the largest standard deviation which means that the dispersion of the number of electricity consumers' data is more spread from its mean than that of other variables.

Table 4.1
Descriptive Statistics

	EC	GDP	PE	CONS	EMP	CI
Mean	7.343	11.399	3.336	8.424	6.966	9.729
Median	7.844	11.207	3.381	8.620	7.672	9.976
Maximum	10.758	12.756	3.684	14.214	8.924	11.408
Minimum	0.000	10.357	3.053	2.565	3.314	7.887
Std. Dev.	3.218	0.863	0.181	4.161	1.912	1.117
Observations	44	44	44	44	44	44

4.3 CORRELATION ANALYSIS

Correlation analysis is used to determine the direction and strength of the relationship between electricity consumption with GDP, price of electricity, number of electricity consumers, employment and capital investment. As illustrated in Table 4.2, the results show that all variables, except the price of electricity, have a positive relationship with electricity consumption. Moreover, GDP and the number of electricity consumers indicate the strongest relationship with electricity consumption.

Table 4.2
Correlation Results

VARIABLES	EC	GDP	PE	CONS	EMP	CI
EC	1.00	0.94	-0.07	0.89	0.76	0.76
GDP		1.00	-0.01	0.93	0.73	0.87
PE			1.00	0.17	0.27	-0.01
CONS				1.00	0.89	0.70
EMP					1.00	0.38
CI						1.00

4.4 PANEL UNIT ROOT TEST

Econometric theory requires that all variables must be stationary conditions before performing cointegration tests. If non-stationary variables are used in the regression, the results will be misleading because of spurious regression. Therefore, it is a preliminary condition to test for unit root before proceeding to other econometric analysis. In this study, the LLC test was employed to perform the panel unit root test. This test was performed on both levels and at first difference for all variables. The results of the panel unit root test are presented in Table 4.3.

Table 4.3
Panel Unit Root Test Results

Variables	**LLC Test**			
	Level		**First Difference**	
	Constant	**Constant &Trend**	**Constant**	**Constant &Trend**
EC	1.235	-0.539	-3.266*	-5.408*
GDP	-0.312	-3.978	-6.319*	-6.248*
PE	1.36	-2.369	-3.369*	-2.097*
CONS	4.497	-3.722	-2.858*	-5.199*
EMP	4.498	1.097	-1.414**	-5.567*
CI	3.608	0.519	-2.816*	-1.635*

Note: *, ** indicates the rejection of the null hypothesis of non-cointegration based on critical values at five percent and 10 percent levels of significance.

As shown in Table 4.3, the panel unit root test results reveal that all variables have a unit root at the level. This indicates that the *t*-statistic values are greater than the critical values, which means that all variables are not significant at the five percent level. Therefore, the null hypothesis should not be rejected because all variables are non-stationary in the level. Moreover, after the unit root test was performed at first difference for all variables, the standard *t*-statistic values became smaller than the relevant critical values for all variables. The results suggest that the null hypothesis should be rejected and all variables are stationary at first difference which is significant at the five percent and the 10 percent level. This confirms that there is no evidence of the existence of unit roots.

Based on the unit root test results, it is proven that the variables are integrated of the same order one denoted by $I(1)$. This means that all variables are non-stationary at the level, but they become stationary after taking the first difference. Therefore, it is appropriate to conduct a cointegration analysis using the panel cointegration and FMOLS estimation to examine the long run relationship electricity consumption, GDP and electricity price as well as other selected variables such as the number of electricity consumers, employment and capital investment.

4.5 PANEL COINTEGRATION TEST

This section reports the results of the panel cointegration test based on Pedroni (1999 & 2004). The residuals of the Pedroni cointegration test allow the electricity consumption model to be determined whether there is an existence of the long run relationship among the variables that are not stationary. The procedure of the Pedroni cointegration test involves seven different test statistics, as discussed in Section 3.6.2. If these statistic values are found to be statistically significant, this suggests that the null hypothesis of no cointegration can be rejected. Therefore, there is a presence of a cointegrating relationship among the variables in the electricity consumption model.

As illustrated in Table 4.4, the panel cointegration test contains the results of the panel statistics and the group statistics. In the panel statistics, if there is a common statistical value within the dimension, the model should be cointegrated. The null hypothesis stated that there is no common statistical value within the dimension, which also means that there is no cointegration in the electricity consumption model. In the group statistics, the alternative hypothesis suggests that there is a significant individual statistical value between the sectors.

Table 4.4
Panel Cointegration Test Results

Test	**Constant Trend**	**Constant & Trend**
Panel *v*-statistic	-0.564417	-1.343405
Panel *ρ*-statistic	0.802972	1.609890
Panel PP-statistic	-6.734494*	-4.971410*
Panel ADF-statistic	-6.567088*	-4.914149*
Group *ρ*–statistic	2.587193	2.785349
Group PP-statistic	-6.752415*	-14.27199*
Group ADF-statistic	-3.041069*	-5.307582*

Note: All statistics are from Pedroni's procedure (1999) where the adjusted values can be compared to the N(0,1) distribution. The Pedroni (2004) statistics are one-sided tests with a critical value of -1.64 (k < -1.64 implies rejection of the null), except the *v*-statistic that has a critical value of 1.64 (k > 1.64 suggests rejection of the null).
* indicates rejection of the null hypothesis of non-cointegration at five percent level of significance.

The results from the panel statistics indicate that two panel statistics such as Panel *v*-statistics and Panel *ρ*-statistics are found to be insignificant at any level. Meanwhile, Panel PP-statistics and Panel ADF-statistics are significant at the five percent level. This means that there is a common statistical value within the sectors (industrial, commercial, mining and agricultural). In the group statistics, the results indicate that the Group PP-statistics and Group ADF-statistics are found to be significant at the five percent level. This means that there is a significant individual statistical value between the economic sectors. Meanwhile, Group *ρ*–statistics are insignificant at any level.

Therefore, four out of seven statistical tests suggest that the electricity consumption model is cointegrated within the sectors. In other words, the null hypothesis of no cointegration is rejected at the five percent level except for Panel *v*-statistics, Panel *ρ*-statistics and Group *ρ*–statistics test. In conclusion, the panel cointegration test results clearly indicate that there is the existence of a stable long run relationship among electricity consumption, GDP, electricity price, number of electricity consumers, employment and capital investment in the model.

4.6 PANEL FULLY MODIFIED OLS ESTIMATION

Given that the panel cointegration test has established evidence that there is a significant cointegration relationship among the variables, further analysis has been taken to estimate a long run electricity consumption equation in order to assess the impact of GDP and electricity price as well as the number of electricity consumers, employment and capital investment. The long run elasticity is acquired through the

FMOLS technique provided by Pedroni (2000). Table 4.5 gives the estimated coefficients of Panel FMOLS by individual sectors namely the industrial, commercial, mining and agricultural sectors, where the dependent variable in the model is electricity consumption.

Table 4.5
Panel Individual FMOLS Results

Sector	**GDP**	**PE**	**CONS**	**EMP**	**CI**
Industrial	0.54**	0.37**	-0.17*	-0.25**	0.21**
	(5.77)	(5.29)	(-1.77)	(-2.86)	(5.14)
Commercial	0.60**	-0.39**	1.17**	-0.32**	-0.02
	(7.78)	(-3.62)	(6.76)	(-2.63)	(-0.42)
Mining	8.06**	-0.34	0.86**	2.21**	-2.56**
	(5.10)	(-0.78)	(5.21)	(2.64)	(-4.03)
Agricultural	-2.21**	-0.15	0.84**	0.19	0.39**
	(-2.96)	(-0.38)	(8.52)	(1.02)	(3.59)

Note: The null hypothesis for the *t*-ratio is $H_0=\beta_i=0$; Figures in parentheses are *t*-statistics.
* and ** is significant with a 90 percent and 95 percent confidence level.

It is observed that Gross Domestic Product (GDP) has an influence on electricity consumption in all sectors and is statistically significant at the five percent level, where the ranges of elasticity are from -2.21 to 8.06. The coefficients of GDP are positive to all sectors, except the agricultural sector. Therefore, a one percent increase in economic performance will lead the industrial, commercial and mining sectors to increase their consumption of electricity by 0.54 percent, 0.60 percent and 8.06 percent respectively in the long run. However, electricity consumption of the industrial and commercial sectors is less responsive to changes in GDP, which indicates that an increase in economic performance does not cause a major increase in electricity consumption of the sectors. In the mining sector, electricity consumption is very responsive with respect to changes in GDP. This could explain an increase in economic performance which leads to the purchase of heavy machinery that requires more electricity, thus causing substantial increase electricity consumption in the mining sector. The signs of computed income elasticity in the industrial and commercial sectors are in line with theoretical expectations and consistent with the findings from Alter & Syed (2011), Inglesi-Lotz & Blignaut (2011) and Javid & Qayyum (2014). For the mining sector, the results could not be compared because no previous studies had covered this sector.

On the other hand, the agricultural GDP has a significant negative impact on electricity consumption. For instance, an increase of one percent of economic performance reduces the agricultural sector electricity consumption by 2.21 percent in the long run. The negative coefficient in GDP suggests that the agricultural demand for electricity is potentially more output responsive and may thereby indicate that other types of energy resources could be used to operate machinery and equipment, as explained in Section 1.2.2.4. Furthermore, Ahmed *et al.* (2011) supported the findings by claiming that the main fuels of the agricultural sector are petrol, diesel and oil products, where these fuels are commonly used to run the machinery. The results of negative responses in the agricultural sector's electricity consumption to GDP are found to be inconsistent with the findings from Alter & Syed (2011) and Javid & Qayyum (2014).

The price of electricity (PE) elasticity has mixed results throughout the sectors. For instance, the results of electricity price elasticity in the industrial and commercial sectors are significant at the five percent level but both sectors indicate a different sign. In the commercial sector, a one percent increase in electricity price causes a reduction in electricity consumption by 0.39 percent. The negative sign in electricity price affirms the theory that price has an inverse relationship to consumption. The coefficient of electricity price elasticity is inelastic, which means that the commercial sector electricity consumption is less responsive with respect to electricity price changes. Generally, electrical energy in the commercial sector is used for cooling and lighting where the lifetime of electrical appliances is relatively long. This implies a low response to electricity price changes. The result is consistent with the findings by Zachariadis & Pashourtidou (2007), Alter & Syed (2011) and Javid & Qayyum (2014) where they found price elasticity to be between the range of -1.83 to -0.26.

In contrast, the electricity price elasticity in the industrial sector shows a positive sign. This indicates that a one percent increase in electricity price will increase the industrial sector's electricity consumption by 0.37 percent. The result contradicts with the theory of demand law which explains that the price should have an opposite relationship to the quantity demanded. This suggests that increases in electricity tariff will give no impact on the industrial sector to reduce production; instead they continue to purchase electrical energy as a main input to run machinery operations as well as for cooling, heating and lighting in the production processes. This could be explained by the fact that the industrial sector enjoys the lowest electricity tariff as compared to other sectors in the economy due to high fuel subsidies by the government. The results are consistent only with the findings by Javid & Qayyum

(2014). Moreover, electricity price elasticity in the mining and agricultural sectors is found to be insignificant.

The results of the number of electricity consumers (CONS) are statistically significant in the long run for all sectors. The sign of consumer elasticity in the commercial sector is elastic as estimated at 1.17, but the mining and agricultural sectors are found to be inelastic as estimated at 0.86 and 0.84, respectively. This means that the commercial sector's electricity consumption is more responsive to changes in the number of electricity consumers rather than that of the mining and agricultural sectors', which is less responsive. The positive relationship between consumers and electricity consumption, especially in the commercial sector, is consistent with the findings by Alter & Syed (2011), but in the agricultural sector it is consistent with that of Ghader *et al*. (2006) and Khan & Qayyum (2009). However, a number of electricity consumers have a negative relationship with the industrial sector's electricity consumption, which is in line with the findings by Alter & Syed (2011). This indicates that with a one percent increase in the number of electricity consumers, the industrial sector's electricity consumption is reduced by 0.17 percent, which could be explained by the lack of availability of sufficient electricity supply (Alter & Syed, 2011) for the derivation of utility.

In this study, employment (EMP) is used to represent the population. As expected, the results show that an increase in the total number of workers leads to an increase in the consumption of electricity in the mining sector. However, employment has a negative long run effect on the industrial and commercial sectors' electricity consumption. This explains that a one percent increase in employment causes a reduction in the electricity consumption of the industrial and commercial sectors by 0.25 and 0.32 percent respectively, but a 2.21 percent increase in the mining sector's electricity consumption. The positive elasticity sign in employment that appears to be related to the mining sector's electricity consumption is consistent only with the findings by Ubani *et al.* (2013).

The estimated model for sectoral electricity consumption also shows that capital investment is an influential factor for electricity consumption in the industrial, mining and agricultural sectors. As a result, a one percent increase in capital investment will cause the industrial and agricultural sectors to increase their electricity consumption by 0.21 and 0.39 percent, respectively. This could be referred to the expansion of existing or new buildings, thus more installations of electrical appliances and machinery operations that lead to an increase in the usage of electrical energy. Meanwhile, capital investment has a negative impact on the mining sector electricity consumption that is probably caused by technological enhancement in energy efficient machinery. The results are not in line with the findings by Pourazam (2012) whereby he discovered that fixed capital was insignificant to explain sectoral electricity demand.

Table 4.6 presents the results from the Panel Group FMOLS in which this test suggests a group mean estimator based on the simple average of the individual Fully Modified OLS for each sector. The results reveal that electricity consumption for the whole panel is significant with respect to the changes in most of the factors, except the price of electricity and employment.

Table 4.6
Panel Group FMOLS Results

Variable	GDP	PE	CONS	EMP	CI
Coefficient	1.75*	-0.13	0.68*	0.46	-0.50*
	(7.84)	(0.26)	(9.36)	(-0.92)	(2.14)

Note: The null hypothesis for the *t*-ratio is $H_0=\beta_i=0$; Figures in parentheses are *t*-statistics. * and ** is significant with a 90 percent and 95 percent confidence level.

For instance, electricity consumption is positively responsive to changes in GDP in the long run. The results explain that in general, one percent increase in economic performance will cause a 1.75 percent increase in the amount of electricity consumed in all the sectors. This means that in the long run, when the country's economy is growing, there will be an increase of 1.75 percent of electrical energy consumed by all the sectors. The results are consistent with previous studies, such as those of Al-Faris (2002), Amarawickrama & Hunt (2008) and Javid & Qayyum (2014), where electricity consumption was responsive to changes in GDP at the aggregate level. These results are also found to be consistent with that of Bekhet & Othman (2001) in Malaysia even though they discovered that income elasticity was less responsive. Meanwhile, electricity price is negatively associated with electricity consumption but the results are insignificant. This means that electricity price is not able to explain electricity consumption for all the sectors in the long run. The results are found to be consistent with that of Bekhet & Othman (2011) and Ivy-Yap & Bekhet (2014) where it was found that electricity price was insignificant.

Other variables such as the number of electricity consumers and capital investment are positively associated with electricity consumption. For instance, with a one percent increase in the total number of electricity consumers, more electricity units are required at 0.68 percent. The results are found to be consistent with the findings by Donatos & Mergos (1991) and Egelioglu *et al.* (2001). Capital investment also indicates a negative relationship with electricity consumption. This suggests that with an increase in capital investment at one percent, electricity consumption will fall to 0.5 percent. It probably means that capital investment has been made in new electricity appliances that use less electrical energy or investment in energy efficient technologies could reduce the amount of electricity used. However, the results from the panel group FMOLS suggest that employment is insignificant to explain electricity consumption in all the sectors.

4.7 PANEL GRANGER CAUSALITY TEST

After establishing the long run relationship based on the panel cointegration tests in Table 4.2, the next step of this analysis is to test whether there is an existence of potential causal relationship among the variables. To achieve the final objective, this study will focus on the direction of causality between electricity consumption and economic growth that represents GDP, electricity price as well as other variables in the panel context. The panel Granger causality test is used to estimate the causal relationship and the results of the estimation are reported in Table 4.7.

Table 4.7
Pairwise Granger Causality Test Results

Null hypothesis	**F-statistics**	**Probality**
GDP does not Granger Cause EC	6.519	0.015*
EC does not Granger Cause GDP	0.199	0.657
PE does not Granger Cause EC	0.148	0.702
EC does not Granger Cause PE	0.505	0.481
CONS does not Granger Cause EC	12.315	0.001*
EC does not Granger Cause CONS	8.465	0.006*
EMP does not Granger Cause EC	24.465	0.000*
EC does not Granger Cause EMP	1.017	0.319
CI does not Granger Cause EC	0.041	0.840
EC does not Granger Cause CI	2.763	0.104

Notes: * indicate the significance at the five percent level

As presented in Table 4.7, the results of the Pairwise Granger causality test revealed that a unidirectional causal relationship exists between electricity consumption and GDP which is significant at the five percent level. It shows the direction of causality running from economic growth to electricity consumption. This supports the conservation hypothesis as explained by Ozturk & Acaravci (2010). Thus, energy policies can be implemented with temporary or no negative effects on economic growth in Malaysia. This relationship is consistent with other previous articles such as those of Ghosh (2002), Yoo (2006), Mozumder & Marathe (2007) and specifically support those finding from Chen *et al.* (2007) in Malaysia.

On the other hand, the Granger causality between electricity consumption and electricity price shows no existence of a relationship in any direction. The results indicate that electricity price does not Granger cause electricity consumption and vice versa, which is insignificant at the five percent level. This means that electricity consumption is not determined and do not cause electricity price in the long run. This relationship does not support those findings by Bekhet & Othman (2011) for Malaysia.

Other variables are also found to have a significant and insignificant causal relationship with electricity consumption. For instance, there is the existence of bidirectional causality between electricity consumption and the number of electricity consumers. This means the variables affect each other simultaneously. Furthermore, employment does Granger cause electricity consumption only in one direction. However, capital investment shows no sign of a causal relationship with electricity consumption in any direction.

4.8 CONCLUSION

It can be concluded that in the long run, sectoral electricity consumption in Malaysia is determined mainly by GDP, electricity price, number of electricity consumers, employment and capital investment. This means that a continuing rise in GDP or economic performance is a contributing factor to increase electricity consumption in the industrial, commercial and mining sectors but reduces the electricity usage in the agricultural sector. Furthermore, an increase in electricity price does reduce and increase the usage of electricity in the commercial and industrial sectors respectively. However, the results of electricity price are not significant to the electricity consumption in the mining and agricultural sectors. Other variables such as the number of electricity consumers, employment and capital investment also have an impact on electricity consumption by sectors, but the results are mixed in terms of the sign of coefficients. For all the sectors, an increase in GDP has a positive effect on electricity consumption in Malaysia. The panel Granger causality test confirms that economic growth influences electricity consumption. Considering the results obtained from sectoral electricity consumption, Chapter Five will discuss some policy implications for each sector.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter gives the general outline of the study as well as the discussion of the findings. It is partitioned into five sections. Section 5.2 takes over the summary of the findings, Section 5.3 contains the policy implication, Section 5.4 explains the limitations of the study and Section 5.5 provides suggestions for future studies. Finally, Section 5.6 discusses the conclusion of the chapter.

5.2 SUMMARY OF THE FINDINGS

The growing demand for electricity and the issue of heavy electricity subsidies have taken a growing interest in the economic literature. It is important for researchers and policy makers to understand the magnitude of consumers' behavioural responses of electricity consumption with respect to the GDP and electricity price changes. However, the majority of the literature only gives attention to estimate electricity consumption at the aggregate level rather than at the disaggregate level such as for economic sectors. The general conclusion of these studies is still inconsistent on the level of elasticity in the GDP and electricity price. These include the direction of causality between electricity consumption and economic growth, as well as electricity price. Therefore, the aim of this study is to conduct an empirical analysis on electricity consumption in Malaysia by focusing on sectoral levels, namely in the industrial, commercial, mining and agricultural sectors. Utilizing the panel data series from 2002 to 2012, this study investigates the responsiveness of sectoral electricity consumption towards the changes in GDP and electricity price as well as control variables such as the number of electricity consumers, employment and capital investment.

To achieve the specific objectives, recent econometric techniques, including the panel cointegration test, the panel FMOLS estimation and the panel Granger causality test, were employed. The first objective is to estimate the long run relationship between sectoral electricity consumption and selected variables which have been tested using the panel cointegration test. The results confirmed that there was an existence of a stable long run cointegration among the variables in four economic sectors over the period of the study.

The second objective is to analyze the impact of GDP and electricity price on electricity consumption in the industrial, commercial, mining and agricultural sectors. Based on the panel FMOLS estimation, the estimated long run response for different sectors reveals that electricity consumption in the industrial, commercial and mining sectors were positively associated with GDP changes, which is in line with theoretical expectations. In the agricultural sector, GDP has a negative impact on electricity consumption. Moreover, a higher electricity price tends to increase and decrease electricity consumption in the industrial and commercial sectors respectively. Other control variables, such as the number of electricity consumers, employment and capital investment, also have an impact on electricity consumption in different sectors, but the results are mixed in terms of the sign of coefficients. In all the sectors, GDP has a significant impact on electricity consumption, whereas the price of electricity was found to be insignificant.

Finally, this study applied the panel Granger causality test to find the potential causal relationship between electricity consumption and economic growth and electricity price in all the sectors. The results indicate that there is a causal relationship running from economic growth to electricity consumption. However, the results of electricity price were found to be insignificant. Other results showed that there was bidirectional relationship between electricity consumption and the number of electricity consumers, employment Granger cause electricity consumption in one direction and no causal relationship was detected between capital investment and electricity consumption.

5.3 POLICY IMPLICATIONS

The growing concerns of a higher demand for electricity and electricity subsidies have warranted attention by the government to implement various energy policies and strategies to achieve its energy goals. Under the utilization objective, the government encourages the efficient use of energy among extensive electricity industries and to minimize wastage of energy consumption. At the same time, the electricity tariff structure will be reviewed as a means to attract high quality investment. Therefore, this prompted the need to examine the impact of income and electricity price specifically on sectoral electricity consumption. This enables the special characteristics of the specific sector to be taken into consideration. The results of this study provide several policy implications and the information could be useful for policy makers in the formulation of appropriate energy policies.

i. The mining sector's GDP has the strongest impact on electricity consumption, and strongly confirms the heavy usage of electricity in the mining sector. The high responsiveness could be driven by increases in electrical machinery and equipment in the production. While the government encourages economic growth across all the sectors, this does not hinder the target to minimise growth of electricity consumption in the mining sector. Therefore, an energy policy should be designed to ensure that the output of energy use in the form of economic values is not sacrificed and provides the industries with an increased economic productivity. Thus, the focus on mining energy efficiency improvement shall be on the adoption of energy efficient equipment and processes. Furthermore, offering financial and tax incentives could be important to catalyze the penetration of energy efficient equipment that consumes less electricity. This will encourage extensive electricity industries to upgrade their electrical equipment and replace the old machinery with new technology. In addition, sufficient energy regulations ensure that industries follow the standard setting requirements of minimum energy performances.

ii. The GDP growth in the industrial and commercial sectors has less impact on the electricity usage of the sectors. This means that the existing energy policy within the industrial and commercial sectors is considerably successful. For instance, the government initiated the Malaysian Industrial Energy Efficiency Improvement Project (MIEEIP) in 1999 to improve the productive usage of energy in eight energy intensive industries in the industrial sector. The project that expired in 2010 has been successfully managed to achieve energy saving measures and attract the involvement of industrial companies in the energy efficiency programme (United Nations Development Programme, 2008). Therefore, this project should be continued and expanded further to other potential sectors such as the commercial, mining and agricultural sectors. Furthermore, the government should continue to take the lead and set an example for practicing energy efficiency among government institutions, government linked companies and the private sector. An example, the implementation of a green building index in government offices such as the Energy Commission building and the Ministry of Energy, Green Technology and the Water building.

iii. With respect to electricity price, the negative estimated coefficient of price elasticity revealed that an escalation in electricity price reduces the commercial sector electricity consumption. However, the low response of electricity price elasticity indicates that the current electricity pricing policy have a significant effect on the commercial sector. Even though a rise in electricity price can restrain the increasing electricity demand, at the same time this could gradually reduce commercial competitiveness. This in turn adversely affects the commercial economic performance and employment. Therefore, policy maker must be careful in reviewing the electricity tariff structure after taking into account the cost and benefit on the government and the private sector.

iv. Furthermore, the current electricity pricing policy is not the best demand management policy to curb the increasing electricity consumption in the industrial sector. As explained in Section 1.2.3, the industrial sector has the lowest electricity tariff compared to other sectors. The cheaper cost of electricity energy due to higher energy subsidies may contribute to the industrial sector consuming electricity extensively in order to increase production. Thus, the electricity pricing policy needs to be restructured in the industrial sector to control the future industrial electricity demand.

v. Moreover, the positive sign of capital investment in the industrial and agricultural sectors proves the importance of adopting energy tax incentives to encourage industries towards the development of new green technologies and projects. Furthermore, an investment in research and development is crucial for the industries to develop their own energy saving products and to enhance research in the field of green technology.

vi. The relationship between electricity consumption and economic growth indicates that economic growth is vital component to stimulate the usage of electricity in Malaysia. However, shocks to economic growth will have a negative impact on electricity consumption. Therefore, while the government always encourages economic growth, at the same time, the government must ensure that the energy policy should aim to increase electricity generation to cope with the current increase in electricity demand. Furthermore, this policy should also be designed to explore the possibilities of renewable energy for electricity generation and encourages the more penetration on energy efficient equipment and practices for the future of sustainable energy and economic development.

In summary, the findings of this study explain that the behavioural response of electricity demand in each sector is different. The inconsistent results of sector responsiveness toward the changes in GDP and electricity price indicate the existence of aggregation bias, which could result in incorrect interpretation. This means with the implementation of current policy, for instance reviewing the electricity tariff, the effect on the group or aggregate level will not produce the same effect to individual sector. Therefore, energy and pricing policies that are applied to these sectors must be carefully formulated to avoid negative policy implication. Thus, it can be suggested that these policies should be reviewed and restructured based upon each sector's characteristics to ensure that the energy and pricing policies are effective and relevant.

5.4 LIMITATIONS OF THE STUDY

In this study, data information is solely confined to the secondary data collected from the reports and authentic publications. Apparently, conducting the current research revealed several limitations.

One of the issues is the difficulty to obtain data for a longer time span in Malaysia especially information about electricity across sectors, which constrains the research on electricity consumption. The majority of electricity data is in the annual time period rather than the quarterly or monthly period and is only available for the past 11 years, from 2002 to 2012. Furthermore, the data on electricity in certain sectors is only available in the shorter time period. Therefore, the results obtained might not be conclusive.

Moreover, the impact on sectoral electricity consumption may not only depend on electricity, economic and demographic factors, but could be determined by other factors such as environment, load demand and technology. However, the information of this specific data is limited but possible to be obtained. Therefore, the insufficient information could result in this analysis not having precise estimates of the impact on sectoral electricity consumption.

5.5 SUGGESTIONS FOR FUTURE STUDIES

As explained in Section 5.4, among the limitations of the current study was the inaccessibility of data especially at sectoral levels. Sufficient time given and easy access to micro data will enable a more comprehensive research to be done in the future. Therefore, this research suggests several areas that might be explored in the further to deepen the understanding of the power industry in Malaysia.

In this study, the area of research is only focuses on the demand side of electricity to investigate consumers' behavioural responses to electricity consumption. Therefore, one possible research area for future studies is to focus and model the supply side of electricity in Malaysia that could be based on issues of insufficient fuel supply for electricity generation, such as natural gas and coal.

Based on the available panel data, this study only estimates an electricity model for the different sectors in the economy. Further research can probably be done on subsectors. For instance, to model electricity consumption based on commercial subsectors such as office buildings, shops and restaurants, the time series or panel data which whichever is appropriate can be applied. By studying the sub-sectors, it will provide in depth information of the sub-sectors' behaviour in response to electricity consumption. In this way, more effective and accurate energy policies can be formulated.

Furthermore, this study on sectoral electricity consumption has concentrated on the national level which incorporated data from different power utility companies such as TNB, SESB and SEB that operate in Peninsular Malaysia, Sabah and Sarawak, respectively. Thus, further research can be done by focusing on these three states rather than a single country. This will provide more accurate results on the sector's behaviour depending on economic conditions and the demography of that region.

The scope of the research can be expanded by considering other factors that have an effect on electricity consumption, such as electricity demand at peak times, which is not covered in this research. Considering the importance of sustainable electricity supply, modelling electricity consumption for peak time of electricity usage can be based on daily, weekly or monthly periods. This additional factor could provide accurate estimates of the impact on sectoral electricity consumption.

Finally, this study has only focused on electricity that represents one of the important energy demands together with other types of energy such as natural gas and fuel oil. Therefore, a survey of consumption on different types of energy is important in order to clarify the issues of energy demand in Malaysia.

5.6 CONCLUSION

The aim of this study is to conduct an empirical analysis on electricity consumption in Malaysia by focusing on sectors in the economy, namely the industrial, commercial, mining and agricultural sectors. Making use of the panel data series from 2002 to 2012, this study investigates the elasticity of economic output and electricity price to provide some information on the responsiveness of sectoral electricity consumption. The results of this study reveal that sectoral electricity consumption in Malaysia is determined mainly by GDP, price of electricity, the number of electricity consumers, employment and capital investment. Nevertheless, the response of electricity consumption by each sector towards the determinants is different. It is important that the formulation of Malaysian energy policy must be taken carefully. Therefore, policy makers should give more attention to specific sector characteristics to facilitate the formulation of appropriate energy and pricing policies.

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