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WHY CLEAN AIR SOURCE OF ELECTRICITY? A PANEL ANALYSIS ON CO_2 EMISSION AND EKC HYPOTHESIS IN 17 MAJOR NUCLEAR GENERATING COUNTRIES

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DECLARATION

We hereby declare that:

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

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

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

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey-Fuller
ARDL	Autoregressive Distributed Lag
BIM	Business Insider Malaysia
CH_4	Methane
CO_2	Carbon Dioxide
DOLS	Dynamic Ordinary Least Square
ECM	Error Correction Model
EKC	Environmental Kuznets Curve
EU	European Union
FMOLS	Fully Modified Ordinary Least Square
FNA	Fukushima Nuclear Accident
GDP	Gross Domestic Product
GDP^2	Gross Domestic Product Squared
GHG	Greenhouse Gas Emissions
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPS	Im, Pesaran, and Shin
LLC	Levin, Lin, and Chu
MENA	Middle East and North Africa
MW	Maddala and Wu
N_2O	Nitrous Oxide
NEI	Nuclear Energy Institute
NONR	Non-Renewable Electricity Production
NUC	Nuclear Electricity Production
OECD	Organization for Economic Co-operation and Development

OLS	Ordinary Least Square
SO_2	Sulphur Dioxide
WDI	World Development Indicators
WEO	World Economic Outlook
WHO	World Health Organisation
WNA	World Nuclear Association
WMO	World Meteorological Organization
UK	United Kingdom
US	United States of America

PREFACE

Global warming, an unnatural climate change phenomenon, is making environmentalist worried, as the most recent year, 2016, was recorded the warmest year. It is found that one of the primary causes of an increase in global warming is the usage of fossil fuels, which comprises of oil, coal and gas. Research also shows that globally, electricity and heat productions are the largest source of carbon dioxide (CO_2) emissions. To generate and produce electricity, fossil fuels are used. But there are other sources of energy that can be used to make electricity which eliminates pollution. Scientists and environmentalists encourage the use of the other sources as they are renewable energy, meaning they are not fast depleting and they do not emit carbon dioxide and other harmful gases.

Nuclear energy is considered to be one those renewable source of energy. Dubbed as clean-air energy, nuclear energy has proven to provide significant environmental benefits. Therefore, a study was conducted to see if nuclear energy affects CO_2 emissions. In order to compare the advantages of using nuclear energy as a source of energy to produce electricity, the variable of electricity production from non-renewable sources was included. Economic growth level of a country will determine a nation's standard of living and how it will affect the usage of energy source and carbon emissions. 17 countries were chosen, with the criteria that they are nuclear generating countries. This research will be a guide to help policy makers initiate a consideration on the usage of nuclear energy in their countries to reduce CO_2 emissions.

ABSTRACT

In this era, degradation of environment that happens in most of the countries is no longer a trifle issue to worry over. Hence, it raised our interest to look deeply into this area of study where we promoted the concern to replace non-renewable electricity production (NONR) for nuclear electricity production. Generally, this study employed panel data approach to analyse the relationships which consisted of data for 17 major nuclear-generating countries over the period of year 1993 to 2013. Meanwhile, there are four independent variables which include the interaction between CO_2 emissions, Gross Domestic Product (GDP) per capita, Gross Domestic Product Squared (GDP^2), NONR as well as nuclear electricity production (NUC) together with Environmental Kuznets Curve (EKC) hypothesis.

Through the obtained results, we observed GDP per capita initially increased the CO_2 emissions in the early stage but eventually it falls over the time, thus the EKC hypothesis is valid and supported in this study. Moreover, to enhance the reliability and accuracy of the analysis, Dynamic Ordinary Least Square (DOLS) and Autoregressive Distributed Lag (ARDL) approach was used. Results showed positive relationship between CO_2 emission and NONR, whereas for CO_2 emission and NUC, it showed negative relationship. Furthermore, the panel Dumitrescu-Hurlin Granger causality test was performed, and it was proven that there is bidirectional relationship between CO_2 emissions and NONR, while the rest of the interactive variables have unidirectional relationships. The results of this research would contribute primarily to the policy makers by giving a better understanding of what drives the level of a country's CO_2 emissions.

CHAPTER 1: RESEARCH OVERVIEW

1.0 Introduction

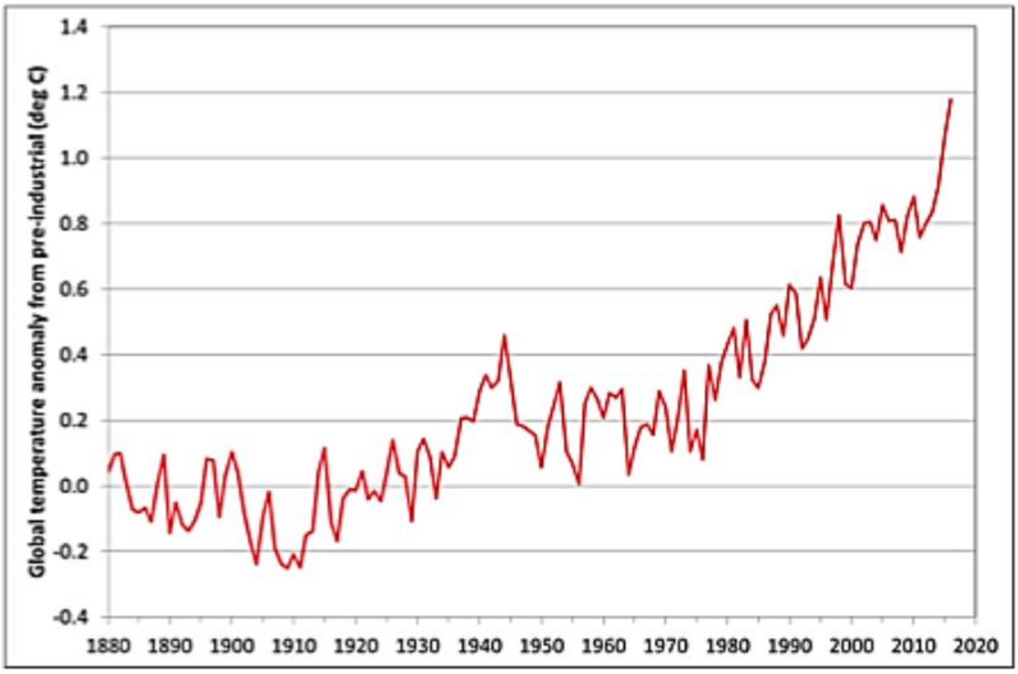
This chapter discusses an overview of the study on CO_2 emission and NONR with a comparison of nuclear electricity production NUC for a panel of 17 major nuclear-generating countries over the period of 1993 to 2013. Besides, the EKC hypothesis presents the relation of GDP per capita on CO_2 emissions. In this chapter, the research background and problem statement would be briefly explained, followed by the research objectives, and research questions. Subsequently, a significance of the study would be conducted as well as the outline for each of the chapters are provided at the end of this chapter.

1.1 Research Background

There is a major concern towards a particular environmental phenomenon related to climate change, with scientists as well as environmentalists calling it unnatural and finding effective ways to curb this issue. Although our planet has experienced climate change due to subtle movements in its orbit, atmospheric changes or varying energy of the Sun, human activities have caused a significantly rapid warming event in recent times. This worrying phenomenon is known as global warming and it means that there is an accelerated rise in the Earth's mean temperature. Experts believe that greenhouse gases, caused by human activities, is the main reason for global warming ("A blanket around the Earth", n.d.).

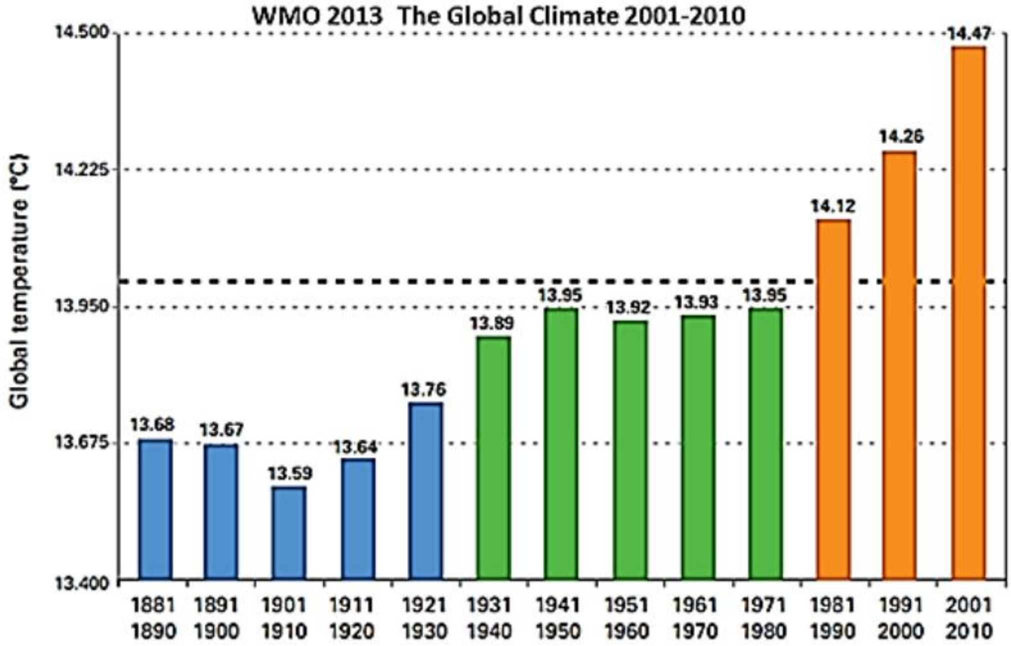
The year 2016 made environmental headlines when the World Meteorological Organization (WMO) confirmed that it was the warmest year recorded, with the temperature anomaly at more than 1.1°C since the pre-industrial times (Figure 1.1). The year 2015 was recorded to be only at 0.06°C. From January 2016 to September 2016, the global temperature has been 0.88°C more than the average temperature of 14°C as shown in Figure 1.2. The average temperature for the year 1961 to 1990 was used by WMO as a guideline. Since 2001, each year showed an increase of 0.4°C compared to the 1961-1990 guideline. As each decade passes, Earth's warming tendencies grow from 0.1°C up to 0.2°C.

Figure 1.1 Global temperature anomaly from pre-industrial times (°C)



Source: WMO, 2016.

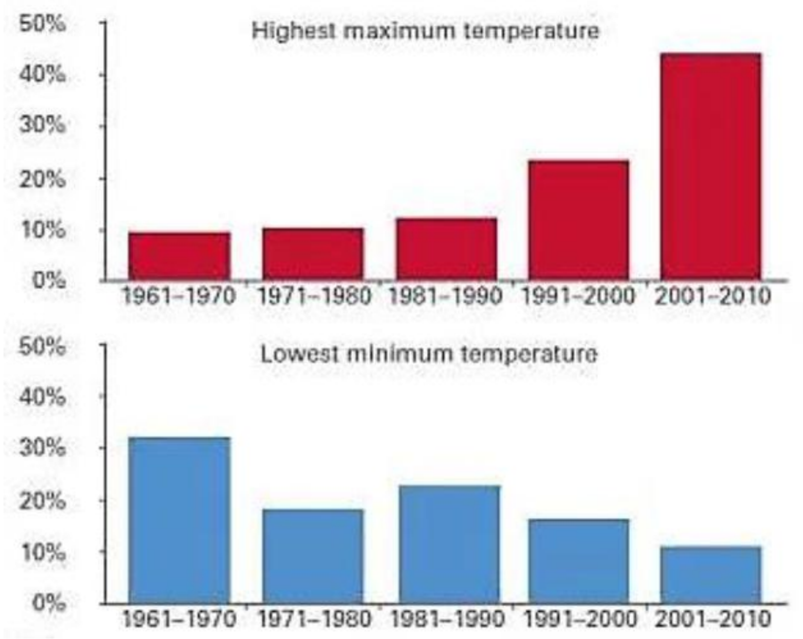
Figure 1.2 Combined surface temperature over land and sea (°C) across decades



Source: WMO, 2013.

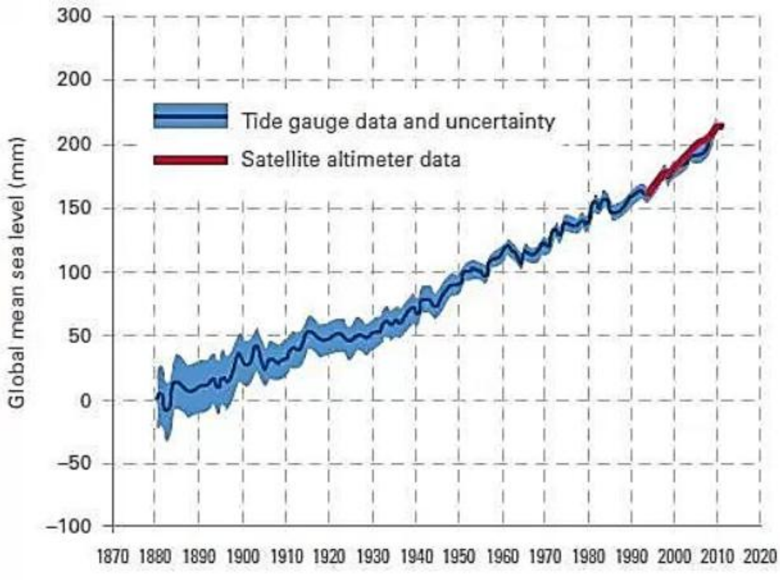
The effects of global warming can be devastating. Firstly, weathers will be at its extremes, where summers will be hotter and winters being colder than usual (Figure 1.3). Besides, an increase in the global temperature melts ice caps. Scientists saw in 2012 the least amount of ice caps in the Arctic Sea and stated that within years, the Arctic sea will be free of ice in the summer time. The melting of ice caps causes an increase in sea levels. According to Bradford (2014), global sea levels have increased by 20cm since 1870, with a rate of increase of 3mm per year over the last decade (Figure 1.4). It will continue to rise in the years to come if greenhouse gases' causing global warming is not controlled.

Figure 1.3 Highest maximum and lowest minimum temperature



Source: WMO, 2013.

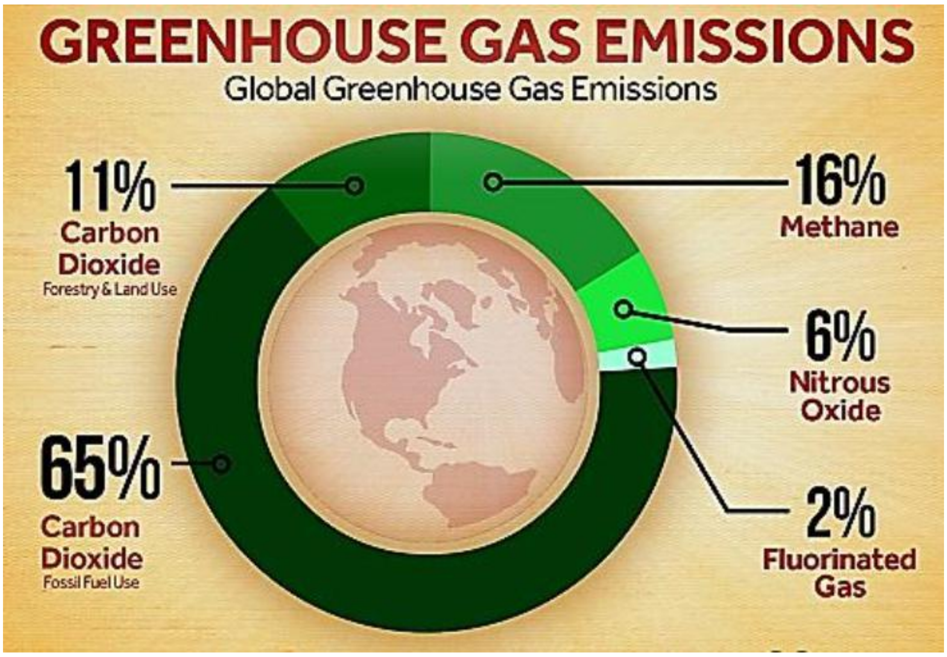
Figure 1.4 Global time series of sea level anomalies from the year 1880-2010



Source: WMO, 2013.

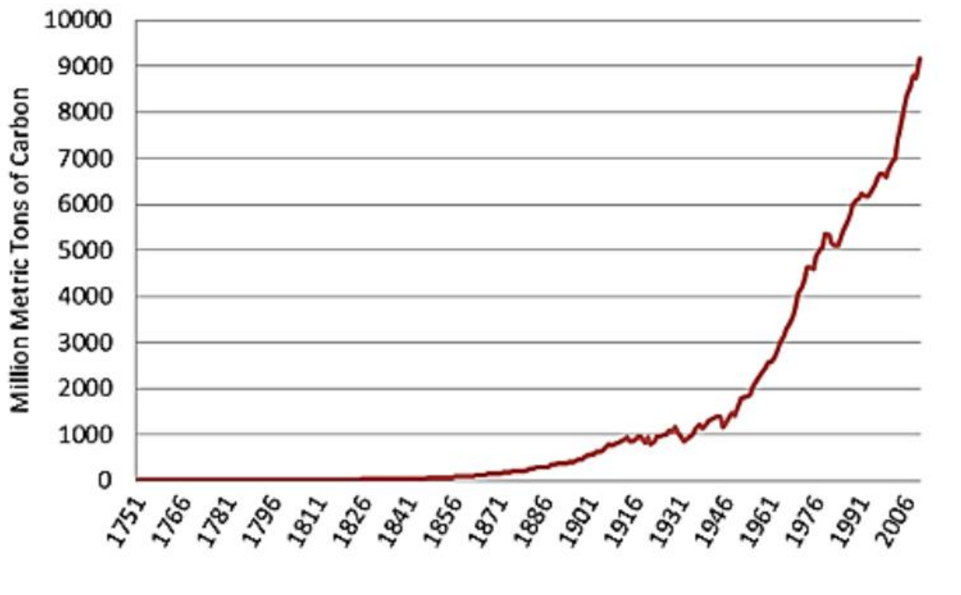
As briefly stated above, a few gases are causing heat to be trapped in the Earth's atmosphere, leading to the greenhouse effect. The gases are fluorinated gas, nitrous oxide, methane, and carbon dioxide. Based on Figure 1.5, it is very clear that one of the main contributors of the greenhouse gas is carbon dioxide, with 65 percent of CO_2 emissions coming from usage of fossil fuels (coal, oil and gas). Humans have been raising CO_2 emissions concentration in the atmosphere since the beginning of the Industrial Revolution (Figure 1.6). In the effort to prevent global warming and reduce greenhouse gases, many industrial countries came to an agreement known as the Kyoto Protocol, which came to force on the 16th of February 2005. Even with this agreement, CO_2 emissions levels in the environment did not decrease (Figure 1.6).

Figure 1.5 Global greenhouse gas emissions (%)



Source: US Environmental Protection Agency, 2016.

Figure 1.6 Global CO_2 emissions 1751-2006 globally

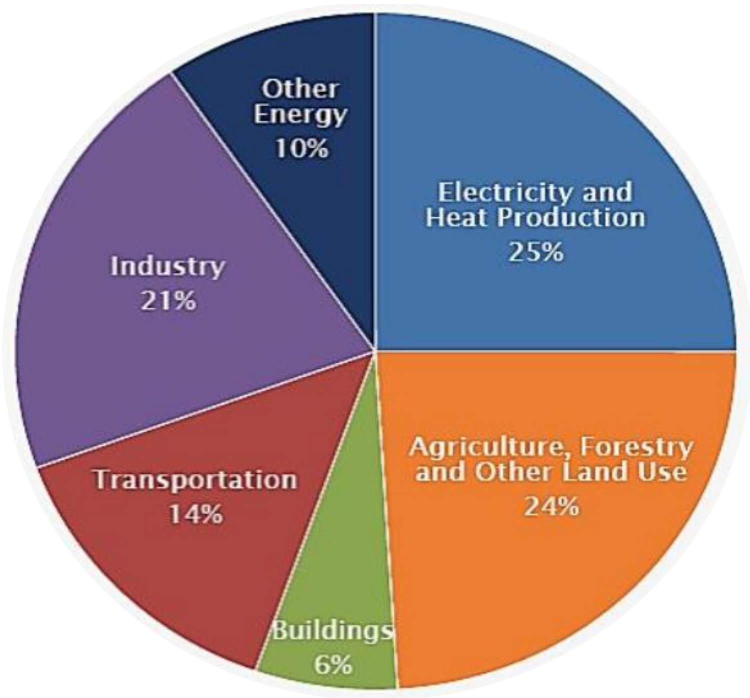


Source: Carbon Dioxide Information Analysis Center (CDIAC), 2013.

Policy makers together with environmental experts have a challenging task of reducing CO_2 emissions while maintaining a country's continuous GDP per capita growth. Studies in the past showed a relationship among GDP per capita and CO_2 emissions. This relationship can be tested using the EKC hypothesis. According to Evangelia (2012), the EKC hypothesis is a simple line of research that discusses the connection between environmental deterioration and economic growth, presented in a curve with an inverted U-shape. As GDP per capita increases in a country, the environmental deterioration increases to a certain level. However, this degradation reduces once it passes the turning point. This threshold level tells us that a rise in GDP per capita can give us a solution to environmental problems.

Jebli and Youssef (2015) mentioned that an increase in GDP per capita indicates a rise in wage. This leads to a demand for better environment quality, which in turn will reduce CO_2 emissions. In fact, it is normal for CO_2 emissions to increase as GDP per capita increases in developing countries with low GDP per capita. Once the threshold point has passed, a decrease in CO_2 emissions, together with a hike in economic growth occurs when a nation becomes a high-income, developed country. However, there are contrasts in the empirical results from the researches that have been conducted (Evangelia, 2012). Details on the evolution and results from the EKC hypothesis will be discussed in Chapter 2.

Figure 1.7 Global greenhouse gas emissions by economic sector



Source: Intergovernmental Panel on Climate Change, 2017

As seen in Figure 1.7, electricity and heat production are the largest source of CO_2 emissions globally. Electricity production involves generating, transmitting and distributing the electricity. In order to do that, coal, oil and gas or simply known as fossil fuels are burned. This is known as non-renewable electricity production. CO_2 emissions and production of electricity from non-renewable sources are correlated. Other than that, electricity is used in households, businesses, and factories. To cater to the increasing demand for electricity usage, more energy from non-renewable sources are used. CO_2 emissions will eventually increase.

According to Jebli and Youssef (2015), in the long run, using energy from non-renewable sources became a vital factor in the rise of CO_2 emissions levels. As GDP per capita of a country increases along with an EKC hypothesis curve, the demand for electricity from non-renewable sources rises. As stated, electricity can also be produced by other sources that are renewable such as hydropower, biomass, wind and solar. Renewable energy has an unlimited supply of fuel. But there is another source of energy that has been in the limelight in recent times and that is nuclear energy. This energy is considered as an imperishable source of energy as there is sufficient uranium to keep the reactors functioning for over a hundred years. The Nuclear Energy Institute (NEI) dubbed nuclear energy as clean-air energy source because it does not emit any greenhouse gases and it can produce electricity every day for 24 hours.

According to the National Nuclear Regulator, the nuclear energy is the crux of an atom (“What is Nuclear Energy?”,n.d.). In order to make electricity, energy is released from the atoms and it happens in two ways, nuclear fission and fusion. When atoms fuse together from nuclear fusion, the energy released forms larger atoms. In nuclear fission, energy is released when smaller atoms are created by the splitting of atoms. To produce electricity, nuclear fission is used by nuclear power plants and uranium is mostly used for this process. The NEI made a comparison on how clean energy differed from other power sources. A mass of uranium, in the size of a pencil eraser has energy equals to 17000 cubic feet of gas, 1780 pounds of coal or 149 gallons of oil.

Aspergis, Payne, Menyah and Wolde-Rufael (2010) states that nuclear energy does not only provide to the needs of many countries, but they also reduce the problems of CO_2 emissions. Aspergis, Payne, Menyah and Wolde-Rufael

(2010) are able to prove that nuclear energy reduces CO_2 emissions in the long run. Nuclear plants saved 10 percent of CO_2 emissions from global energy use (Adamantiades & Kessides, 2009). Where the EKC is involved, as GDP of a country continues to increase, people will demand for a better quality of life. Therefore, there will be an increased insistence for clean-air energy. When more electricity is being produced from nuclear sources, the less CO_2 emissions is being emitted into the environment. This satisfies the curve's inverted U-shaped theory. More on NONR and NUC will be elaborated in Chapter 2.

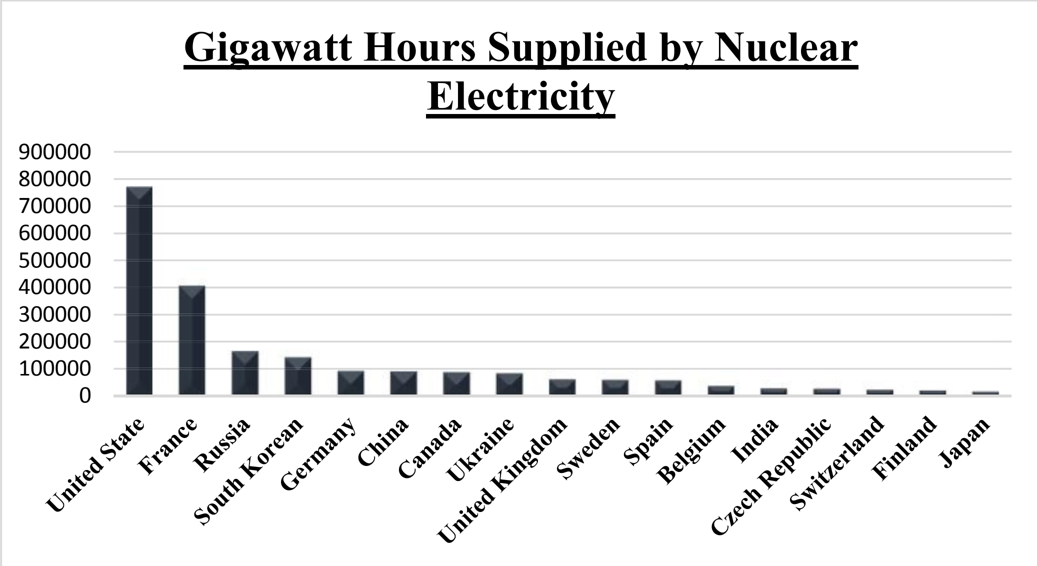
Although NUC brings advantages in terms of lowering CO_2 emissions, there are reasons why nuclear energy is seen as a disadvantage. The major hurdles faced when it comes to nuclear energy is the low probability, high consequence accidents, radioactive waste disposal concerns and high, uncertain costs (McCombie & Jefferson, 2016)

Firstly, nuclear radiation accidents pose great threats to the environment and people. For example, the Chernobyl disaster and the Fukushima Nuclear Accident (FNA). The Chernobyl disaster occurred due to flaws in the reactor design, which was operated by plant operators who were trained inadequately (WNA, 2016). It caused significantly large amounts of deaths in the Ukraine, and to this day, Ukrainians are dealing with the effects of the incident. The FNA in Japan happened due to natural disasters. The death rate was lower compared to the Chernobyl disaster, but the environmental impacts were still devastating. Humans cannot protect themselves completely from nuclear disasters. However, safety precautions, intensive training and knowledge on dealing with nuclear energy, together with skilled labor can help lower the chances of these accidents from occurring.

Besides that, radioactive wastes, when not disposed of properly or not stored safely, are highly dangerous and let off radiation even after thousands of years. Radioactive waste is any material, in solid, liquid or gas that has radioactive nuclear substance. It is considered to be waste if it has been in the reactors, producing heat and electricity for more than 3 years (Conserve Energy Future, 2017). The wastes are able to emit radiation even after a thousand years, which is the reason why these wastes must be disposed of correctly. Radioactive wastes can threaten aquatic life if it is allowed to runoff from land. Scientists claims the wastes take 10,000 years to neutralize. That being said, water is still a great cooling and shielding tool and radioactive wastes can be safely stored in a storage pool for more than 50 years.

Lastly, the usage of nuclear energy for electricity production and others requires the set up nuclear power plants, which needs a lot of investments. According to Conserve Energy Future (2017), the cost of a new nuclear power plant construction increased from 2-4 billion dollars per unit to 9 billion dollars per unit between the years of 2002-2008. It also takes 5 to 10 years for the power plant to be fully functional and requires a series of legal formalities. Nuclear energy needs high initial capital cost, takes a long time and tedious formalities. But if a country is a well-developed country, with economic and political stability and suitable geographical conditions, it is possible to go through with the plans of using nuclear sources.

Figure 1.8 Gigawatt Hours Supplied by nuclear electricity in 2014



Source: Business Insider Malaysia (BIM), 2014.

By using Figure 1.8, 17 countries were chosen for our study according to the overall electricity amount made by nuclear power. These countries were chosen by BIM (2014) after an analysis was done on a statistics provided by UN's International Atomic Energy Agency (IAEA). The countries, from lowest to highest of electricity produced using nuclear power are Japan, Finland, Switzerland, Czech Republic, India, Belgium, Spain, Sweden, United Kingdom (UK), Ukraine, Canada, China, Germany, South Korea, Russia, France and the Unites States of America (USA).

Table 1.1 below shows that the USA produces the largest amount of electricity from nuclear power at 770,719 gigawatts per hour. 19 percent of the total electricity is produced using nuclear power. They have a total of 100 current reactors. Japan produces the least amount of electricity using nuclear power in this list of countries. Only 17,230 gigawatts per hour of electricity is nuclear electricity, which means 2.1 percent of the total electricity in Japan is using nuclear power. Japan has a total of 50 reactors currently.

Among these 17 countries, USA, France, Canada, Germany, UK, Spain, Sweden, Czech Republic, Belgium, Japan, Finland and Switzerland are classified as countries with developed economies. Russia and Ukraine are countries with economies in transition which means their economy is changing to a market economy from a centrally planned economy and they have to go through a series of structural transformation. South Korea, China and India fall under the classification of developing countries.

The top four countries or regions that have the highest CO_2 emissions are China (30%), USA (15%), the European Union, EU (10%), and India (6.5%) (PBL Netherlands Environmental Assessment Agency, 2015). All the countries chosen for this study, except Russia, South Korea, Ukraine, Japan, Canada and Switzerland matches with the countries that emit the most CO_2 emissions globally (61%). EU country from the 17 countries chosen: Belgium, Czech Republic, Finland, France, Germany, Spain, Sweden, UK.

Table 1.1 Seventeen countries generating the most nuclear power

	Gigawatt hours supplied by nuclear electricity	**Total amount reactor**	**Total electricity produced by nuclear (%)**
USA	770719	100	19.00
France	407438	58	74.80
Russia	66293	33	17.80
South Korean	143550	23	30.40
Germany	94098	9	16.10
China	92652	17	2.00
Canada	89060	20	15.30
Ukraine	84886	15	46.20
UK	63964	18	18.10
Sweden	61474	10	38.10
Spain	58701	8	20.50
Belgium	38464	7	51.00
India	29665	20	3.60
Czech Republic	28602	6	35.30
Switzerland	24445	5	35.90
Finland	22063	4	32.60
Japan	17230	50	2.10

Source: BIM, 2014.

According to the WNA (2017), Japan has more than 50 reactors, which provided 30 percent of the nation's electric power and expected to increase by 2017. Japan has a shortage of minerals and energy, so they focused on nuclear energy to reduce the country's dependence on oil imports. However, the Fukushima Nuclear Accident (FNA) occurred. Based on an article by WNA, updated in April 2017, a 15-metre tsunami, triggered by a major earthquake disabled the supply and cooling of all three Fukushima Daiichi reactors. This resulted in the FNA on March 11th of 2011. Because of this accident, there were large protests from the public to abandon nuclear power. Although Japan has third most amount of reactors among this list of countries, the accident has caused a reduction in operable power plants. There are currently 42 operable power plants, which may be able to restart.

1.2 Problem Statement

Rising levels of atmospheric CO_2 emission is now at an alarming rate as well as widely recognized due to its seriousness. Ultimately, the best solution for the good of future generations is to reduce as much CO_2 emissions being discharged. In moving to new globalization stages, a substantial increase of energy demand and energy dependence of countries in both production and consumption of electricity foresee that energy will be one of the major concerns in the new era. Hence, it leads to a huge requirement of seeking alternative and renewable sources of energy (Saidi & Hammami, 2015).

Next, living standard improvements result in greater pressure to reduce emissions in most of the countries (Markandya, Gonzalez-Eguino, Criqui & Mima, 2014). As countries are on the progress of transforming to an economy of new climate, it creates an argument about whether countries' growth is able to coexist with climate stabilization. On the contrary, an argument regarding the stabilization of climate stimulating the growth in a country's economy has been questioned. In the Clean Power Plan analysis which proposes to limit carbon emissions from existing fossil fuel-fired electric generating units, the USA Energy Information Administration predicts that it would lead to sustained periods of GDP-GHG disintegration when improving to a cleaner electricity system after 2020.

Furthermore, according to the World Nuclear Association (WNA), a review of more than twenty studies investigating the greenhouse gas emissions (GHG) created by various forms of electricity generation has been executed. From the outcome, it shows that generating electricity from non-renewable energy leads to greenhouse gas emissions far higher compared to the use of nuclear or other renewable energy for electricity generation. Previous researchers reported that, without any policies implemented or actions taken to reduce such emissions, the concentration of GHG in the atmosphere could eventually double its preindustrial levels by as early as 2035 (Bekhet & Othman, 2017). Hence, in the present studies, we compared the total CO_2 emissions produced from nuclear and non-renewable energy in affecting countries' economic growth.

Lastly, the EKC hypothesis posits that environmental degradation increases at the initial stage of countries' economic growth. However, when it reaches a certain level of economic growth, called turning point, it will reverse its process as people would demand for a better environment. Research findings predicted that energy consumption in developing countries such as Russia and China would rise more rapidly than expected. According to World Health Organisation (WHO), China is known for being the world's deadliest country for air pollution. Based on the analysis done by WHO, more than 1 million people died from dirty air in China in 2012, roughly 600,000 and 140,000 respectively in India and Russia. Therefore, growth and development economists are concerned about the continuity of productions in economies while the environmental issues evolve (Özokcu & Özdemir, 2017). It is an extremely great challenge for any country to balance off both pollution levels and economic growth. It is in hope that this study would contribute to the literature on addressing the problem with credible policies.

1.3 Research Objectives

1.3.1 General Objective

The aim of this paper is to identify if CO_2 emissions are influenced when clean energy from nuclear source is present. The ultimate goal is to determine if there is a negative link between CO_2 emissions and NUC. Using information from 17 major nuclear-generating countries, it can encourage other countries to decide on switching to nuclear production. A country's economic growth will determine its CO_2 emissions levels, as the economic growth influences the lives of the citizens of the country, thus determining how well they would want their standard of living to be.

Using the EKC hypothesis, it will show how changes in economic growth affect the CO_2 emissions in that country. With CO_2 emissions being the dependent variable and the independent variables being GDP per capita, GDP^2, NONR and NUC, the results from this research will give a clearer picture on what can bring a difference to CO_2 emissions in the selected countries.

1.3.2 Specific Objective

This paper aims to:

a) Study the relationship of GDP per capita, NONR, and NUC respectively on CO_2 emissions in the short run and long run.
b) Determine the causal direction among CO_2 emissions, GDP per capita, NONR and NUC.
c) Determine the validity of the EKC hypothesis.

1.4 Research Question

1. What is the relationship between CO_2 emissions and GDP per capita, CO_2 emission and NONR, CO_2 emissions and NUC?
2. What is the causality direction between the GDP per capita, NONR and NUC on CO_2 emissions?
3. Does the EKC hypothesis exist in the case of 17 countries?

1.5 Significance of the study

The findings of this study will redound to the benefit of countries considering NUC as an important role in the future for carbon free energy system. NUC provides stable energy generation and lowers the carbon technology in the future as reported in World Economic Outlook (WEO) (Ahokas & Söderholm, 2016). Besides, resources of NUC can last significantly longer than some other energy such as fossil fuels and it does not emit much CO_2 emissions into the atmosphere. Thus, the results derived from this study will be able to combat against climate change and to chart a cleaner future for environmental quality.

As with a million things in life, there comes a point where “more is better”. Therefore, before adding data for every potential predictor into the regression model, one thing notable called multicollinearity problem should be taken into consideration (Cerdeira Bento & Moutinho, 2016). In fact, sometimes adding more factors into a regression model might fail to make things clearer, and eventually makes it harder to meet the accuracy and reliability. Since GDP and GDP^2 are the main estimators to prove the EKC hypothesis, it will lead to multicollinearity problem. The contribution of this study is to avoid the problem, hence two methods were used in this study to prove the reliability and strengthen the results.

Furthermore, as we can see the Earth sound an urgent alarm that if we do not address the environmental issues today, it could indeed cause undesired and worse condition that might persist for many coming years. There are extensive researches particularly on electricity consumption and shortage on electricity production. Therefore, this study will mainly contribute to the future researches in uncovering critical areas involving environmentally beneficial electricity production that many researchers still have not explored. In a nutshell, this study is able to provide better insights to the government on using NUC instead of NONR. Thus, they could come out with a better scheme to avoid the degrading conditions of the environment before it turns even worse in future.

1.6 Chapter Layout

In Chapter 2, literature review will be provided regarding existing empirical studies on CO_2 emissions and EKC hypothesis. Meanwhile, Chapter 3 will be describing the theoretical framework, presenting the data collections, then analysing the selected econometric methodologies and the econometric tests results of its models. Next, the findings and empirical results of this study will be reported in Chapter 4 as well as the interpretation of the results. Lastly, Chapter 5 highlights the summarization of results, policy implication, limitations and recommendations towards the relevant studies.

1.7 Conclusion

Chapter 1 provided an overview of the explanation on the research background and current issues that most people are concerned about today. Problem statement, research objectives, and the research questions explains how the study will be conducted. It is followed by the significance of the study, which determines the contribution to the body of knowledge for researchers. In short, all this information in Chapter 1 would become the foundation for the advanced statistics discussed in the next chapter.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

The first chapter elaborated on the research background, problem statement, objectives (general and specific), and the significance of the on a study on CO_2 emissions in 17 countries which uses nuclear power to generate electricity. Before conducting the empirical analysis, we will review the works of past researchers' that relates to CO_2 emissions, GDP per capita, NONR and NUC. Many journals were reviewed and it is found that there are limited studies that can support the findings of this study.

In chapter 2, using past researchers' studies, an extensive review will be done on the dependent variable, CO_2 emissions. It is followed by the independent variables GDP per capita, NONR and NUC. The methods used by the researchers to carry out their studies will be explained. This chapter also deeply discusses the EKC hypothesis, which is widely used to test the relationship between environmental degradation and economic growth. This part will also see if the EKC hypothesis can involve any other theory, as a proposed theoretical framework, which will be used for this research. Towards the end of this chapter, we will include the conclusion to summarize what has been discussed.

2.1 Review of the Literature

2.1.1 Carbon Dioxide (CO_2) Emissions

CO_2, methane (CH_4), nitrous oxide (N_2O) and sulphur dioxide (SO_2) are major contributors of greenhouse gases (GHG) account, leading to the global warming in the Earth. According to World Bank (2017), CO_2 emissions are those resulted from fossil fuel combustion and manufacture of cement. Primarily, the largest share of greenhouse gases coupled with global warming mainly attributable by-products of energy production and consumption. CH_4 emissions are from the production, handling, transmission, energy use and combustion of fossil fuels and biofuels. N_2O emissions are emitted from agricultural biomass burning, industrial processes, and livestock management. Besides, SO_2 are emissions that generate from mankind sources, accounted for 99 percent in the air. The main source of SO_2 is industrial activities such as generation of electricity from non-renewable sources and burning of fossil fuels, also, the presence of the emissions from motor vehicle which generated fuel combustion (Department of the Environment and Heritage, 2005).

Despite the vast amount of studies that have investigated the relationship between income and greenhouse gases (GHG) by using CO_2 emissions, there is still some literature focusing on other GHG. Other than CO_2 emissions, CH_4, N_2O and SO_2 also play an important role in contributing the GHG as stated above. The validity of EKC hypothesis has been used to investigate different pollutants like CH_4, N_2O, F-gases, and SO_2. Roca, Padilla, Farre´ and Galletto (2001) considered CO_2, CH_4 and N_2O as the first three pollutants. Three of them are of special relevance because they are the main causes of global warming and release emissions that contribute to greenhouse effect. SO_2 emissions mostly affect local population and a few numbers of important emission sources and less investment can be used to reduce their emissions easily. Methane gas is one of the gases that is not likely to follow the EKC hypothesis in this study. The key factor of the issue which appeared against the empirical relationship postulated by the EKC hypothesis due to nitrous oxide occurs with other greenhouse gases.

Cho, Chu and Yang (2014) aim to test the EKC hypothesis by using such measures of air pollution, namely, total GHG, CH_4 and N_2O in the Organization for Economic Co-operation and Development (OECD) countries. The results showed that a quadratic relationship existed in the long run and was found to support existence of the EKC. Furthermore, many researchers have done the empirical studies particularly on SO_2 from SO_x and mostly the cases have shown a valid inverted U-shape curve. There were many others researchers that have done the summary of various studies of EKC for SO_x, especially in the studies by Winslow (2005) and Stern (2004). Miah, Masum and Koike (2010) proved that the observation on the global EKC hypothesis for CO_2, NO_x and SO_x support the theme of EKC hypothesis. They indicate that the turning point is at the level of the highest income per capita to diminish the emission in the EKC. According to a recent study by Atasoy (2017), it was widely believed that greenhouse gases such as CH_4, N_2O, SO_2, and CO_2 contribute to a warmer climate.

Among all the GHG, carbon dioxide is the main culprit behind global warming. Thereby, most of the studies have discussed numerous determinants of CO_2 emissions around the globe. Since CO_2 emissions are considered as the primary contributor to global warming, it has been the most widely used indicator in the EKC literature (Baek, 2015). Another study supported by Atasoy (2017) determined that around 75 percent of the global greenhouse gas emissions are caused by CO_2. According to the Intergovernmental Panel on Climate Change (IPCC) report (2007), CO_2 alone contributes roughly 76.7 percent of the total GHG. Increasing emissions of these gases in the world have threatened the issue of global warming.

In studying the EKC hypothesis for multiple studies, they have used the CO_2 as an important proxy about the environment. As a result, we attempt to select the CO_2 emissions as our dependent variable to be an indicator of pollutants level, to observe the theoretical linkage between the independent variables and EKC hypothesis. Using the CO_2 emissions as an indicator of pollution level and the testing the validity of the EKC hypothesis are widely examined by some of the researchers over the years.

A study examined that the CO_2 emissions are affected by renewable and non-renewable energy, real income and trade openness in the EKC model over the period of 1980 to 2012. Dogan and Seker (2016) used CO_2 emissions as a dependent variable, an indicator of environmental pollution and the EKC is found to be supported by the European Union as the elasticity of CO_2 emissions with GDP and GDP^2 are positive and negative respectively. Moreover, Danish, Zhang and Wang (2017) employed the EKC hypothesis as primary contribution in their research in order to test individual countries by testing the significance of renewable energy and non-renewable energy consumption. They found the evidence to support the existence of EKC hypothesis in the case of Pakistan over the period of 1970 to 2012.

According to Cerdeira Bento and Moutinho (2016), they studied the effect of CO_2 emissions on the NONR and renewable electricity production, and international trade. Thus, EKC hypothesis is found to be validated with the reduction of pollution levels over time in the case of Italy. Besides that, in the case of 20 European countries, researchers Moutinho and Robaina (2016) used CO_2 emissions as a proxy of air pollution in Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands, Slovenia, Poland, Portugal, Slovak Republic, Spain, Sweden, Estonia and UK. They proved the validity of the EKC hypothesis at the same time.

Some of the previous studies found that the EKC hypothesis is not always supported in all the sample of countries in both the short and long run. A study by Ahmeda and Long (2012) discovered that the short run EKC hypothesis is not found but it was validated in the long run and concluded that the relationship between CO_2 emissions and the other four explanatory variables such as energy consumption, economic growth, trade openness and population growth in Pakistan. Further supported by Bernard, Gavin, Khalaf, and Voia (2015), they examined the CO_2 emissions as a proxy of air pollutants to link with the EKC hypothesis and found the validity of EKC hypothesis in OECD countries but not elsewhere. Another study on 25 selected African countries was done by Zoundi (2016), using CO_2 emissions as a proxy for air quality. This study examined the effect of GDP, renewable energy, energy consumption and population on CO_2 emissions by applying the panel cointegration in the period of 1980 to 2012. The results provided no evidence of a total validation on EKC predictions for the sample of countries but CO_2 emissions were found to increase with the income per capita in the first stage of EKC hypothesis.

A recent study by Apergisa, Christoua and GuptaWhere (2017) used CO_2 emissions as a proxy of environmental degradation and EKC hypothesis is found to be validated across 10 states out of 48 states in United State. There is no relationship between CO_2 emissions and personal income across some states over the period of 1960 to 2010. Another research done by Alam, Murad, Noman and Ozturk (2016) investigated the effect of income, energy consumption and population growth on CO_2 emissions as an indicator of pollution levels in India, Indonesia, China, and Brazil over the period of 1970 to 2012. The findings showed that the theory of EKC for CO_2 emissions does not significantly hold for India. However, for Indonesia and Brazil, the theory of the EKC for CO_2 emissions does hold in the short and long run. EKC hypothesis also holds for China but only in the long run.

However, some studies found that the EKC hypothesis does not hold and is invalid among the countries. Mrabet and Alsamara (2017) studied the effect of real GDP, the square of real GDP, the energy use, the financial development and the trade openness on the CO_2 emissions in the case of Qatar for the period of 1980 to 2011. The findings showed that the EKC hypothesis was invalid when using the environment indicator of CO_2 emissions. Another study by Soytas, Sari, and Ewing (2007) used CO_2 emissions as a proxy of pollution levels to examine the effect of energy consumption and GDP on CO_2 emissions. This study took the EKC hypothesis into account and found some evidence against the EKC hypothesis in the United State. Mugableh (2013) used CO_2 emissions as a proxy of pollution level to examine the effect of GDP and energy consumption on CO_2 emissions for Malaysia over a period of 1971 to 2012. Thus, the findings showed that the existence of EKC hypothesis does not hold between the relationship of GDP and CO_2 emissions in the Malaysian economy in the long run.

2.1.2 Relationship between GDP and CO_2 Emissions

Previous researchers Danish, Zhang and Wang (2017) carried out a recent study for Pakistan between the periods of 1970 to 2012. They stated that in both long run and short run path, there is positive sign of the coefficient of GDP per capita which indicates that CO_2 emissions increase with national growing income; meanwhile, GDP^2 which is the indicator used to conduct EKC hypothesis have negatively significant relationship with CO_2 emissions both in the long run and short run. The findings provide strong support for the presence of the EKC. This is referring to CO_2 emissions increasing at the initial phase of the economic growth and later it starts to decline after reaching a turning point of economic growth which we call inverted U-shaped EKC hypothesis. On the other hand, other researchers Ahdi et al. (2015) found cubic N-shaped curve in United Kingdom and inverted N-shaped curves for Italy and Japan which oppose the traditional EKC hypothesis for these countries.

Other than that, regarding to inverted U-shaped EKC curve, some studies found that there is more comprehensive information related to the relationship between CO_2 emissions and economic development can be disclosed through N-shaped curve. It could be considered as an inverted U-shaped curve supplement. N-shaped curve appearance is likely influenced by the complex reaction of various factors. It can be well explained by some examples such as energy crisis and government policies. The comparison in results revealed that the N-shaped model is more suitable to explain developed countries. Meanwhile, monotonically increasing model or inverted U-shaped model is more preferable for less developed or developing countries (Yang, Sun, Wang, Li, 2015).

Besides, a study conducted by Al-mulali (2014) utilized panel data methodology instead of time series analysis in order to eliminate the weaknesses of controlling heteroscedasticity, endogeneity and serial correlation. Therefore, 30 major nuclear energy-consuming countries had been chosen as his research area and panel mode was used, taking the period of 1990 to 2010. The findings of panel Fully Modified Ordinary Least Square (FMOLS) indicated that the GDP per capita of 19 out of 30 chosen countries has a positive long run relationship with CO_2 emissions, whereas GDP per capita does not have a significant effect on CO_2 emissions in 8 countries. Furthermore, GDP per capita growth has a long run negative effect on CO_2 emissions in 3 countries among the 30 countries. This study yields conflicting results due to diverse characteristics in every single country. Thus, it is argued that results for one country cannot be generalized for another country regardless it is in the same period of time.

According to previous researchers, a positive long-run and short-run relationship was found between GDP per capita and CO_2 emissions, but for Turkey, GDP has no causal effect on the CO_2 emissions (Soytas & Sari, 2006). Other than that, another study performed the Johansen co-integration test and based on the results, it showed that a 1 percent rise in the GDP per capita may cause a 1.191 percent rise in the CO_2 emissions level, ceteris paribus (Emmanouil Hatzigeorgiou, Heracles Polatidis, Dias Haralambopoulos, 2010). However, researchers argued that the results of their studies showed significant time-varying causalities running from GDP per capita to CO_2 emissions for countries Italy, Japan, and the UK (Ahdi et al, 2015).

In addition, another debate was the relationship between GDP per capita and CO_2 emissions in developed countries. It is identical with the relationship in developing countries, whereby both generate same result, indicating that higher GDP per capita leads to more CO_2 emissions, and the increase in CO_2 emissions would cause worsening economic condition in short-run. Nevertheless, the increase in CO_2 emissions eventually leads to economic growth improvement and thus, the environment is better off in the long-run (Chen, Chen, Hsu, & Chen, 2016). According to Narayan, Saboori and Soleymani (2017), there is a positive relationship between economic growth and CO_2 emissions which was investigated in 181 countries. 49 of those countries was found income growth that could help in reducing emissions in the future.

Next, Ahmad and Du (2017) carried out the testing on relation of CO_2 emissions with economic growth; it has positive and significant relation with the economic growth, having a coefficient of 0.39 in the long run. The reason of CO_2 emissions' positive coefficient can be that heavy industries are the source of economic growth and they are injecting CO_2 emissions in the environment. It means that if Iran intends to reduce CO_2 emissions, it has to sacrifice the economic growth or may have to find an alternative to control emissions like increase in energy efficiency.

Besides that, previous researchers Yousefi-Sahzabi, Sasaki, Yousef and Sugai (2010) found verification to support the framework which exhibits the significant correlation between CO_2 emissions and economic development during the years of carrying out investigation in Iran. This relationship is examined and discussed for the energy sectors of the country as well. The results proved that there is a positively strong correlation throughout the study period except for agricultural.

In majority sectors, the intensity of CO_2 emissions, which is the emissions per unit of GDP per capita does not convey rising trends. However, the economic growth encouraged the rapid increase of absolute emissions.

2.1.3 Relationship between NONR and CO_2 Emissions & NUC and CO_2 Emissions

Electricity is essential for all aspects of our lives today, and there are more countries generating the electricity with each passing year. The main electricity product is generated from fossil fuels, nuclear, hydropower plants, solar, biofuels and wind ("OECD Data, Electricity generating", 2017). From the International Energy Agency (IEA) statistic 2016 edition, there are more than half of the world annual energy related to CO_2 emissions from the electricity sector ("CO_2 Emissions from Fuel Combustion Highlights 2016 edition", 2016). According to Liu and Lin (2009), as well as Maryam, Mittal and Sharma (2017), CO_2 emissions will become a threat to the global economy as time goes on, and thus, the choice of generation technology has played an important role to reduce CO_2 emissions footprints in the future. Although the recent literature tends to move towards the impacts of renewable energy source on CO_2 emissions, many studies have paid attention to the importance of nuclear electricity source on CO_2 emissions.

According to Nuclear Energy Institute (2017), nuclear source plays an important role in generating electricity by producing the least emissions in the Earth and has been known as low carbon emissions in many countries. It is supported by the study of Apergis, Payne, Menyah and Wolde-Rufael (2010) as they found that the nuclear electricity source is negatively-statistical significant impact on CO_2 emissions. Similarly, Baek and Pride (2014) explored that nuclear energy source tends to reduce CO_2 emissions for all countries. The results show that there is negative long-run relationship between nuclear energy source and CO_2 emissions among all the countries in this research and thus, evidence has been provided as the role of nuclear energy will result in reducing CO_2 emissions.

Besides, research studies for 19 developed and developing countries by using the panel error correction model, Apergis and Payne (2010) found that nuclear energy consumption played an important role to reduce CO_2 emissions in both short run and long run from the period of 1984 to 2007. Besides, they also use the panel Granger causality tests to examine the causal relationship between nuclear energy consumption and CO_2 emissions. It is supported by Saidi and Ben Mbarek (2016), who also explored the causal relationship between both variable. In addition, Wolde-Rufael and Menyah (2010) use the error correction model (ECM) to test the relationship between nuclear energy consumption and CO_2 emissions and it results in a statistically negative significant association between both variables.

Marques, Fuinhas and Nunes (2016) used panel ARDL test to approach the relationship of nuclear source and CO_2 emissions in France. They noted that there is negative relationship among nuclear sources and CO_2 emissions in both short-run and long-run in France, thus their results have shown the evidence. Nuclear Energy Agency (2002) proposes that the relationship between the indicators of CO_2 emissions and nuclear electricity source is also an important study that needs to be explored in the literature review. The previous study by Jiang (2011) documented that the carbon reduction effect for nuclear power development is obvious. The result showed that a direct reduction in CO_2 emissions, accounted for 7.5 percent by replacing the fossil fuel with nuclear power in the case of China.

In USA, Menyah and Wolde-Rufael (2010) explored the causal relationship between CO_2 emissions and nuclear energy over the period of 1960 to 2007 by using the Toda and Yamamoto test. Their investigation confirms that nuclear and CO_2 emissions have unidirectional causality relations between each other. Alternatively, these studies show that a large amount of electricity production will produce lower carbon emissions or no emission. However, some of the research done by Benjamin

(2008) found that nuclear energy is not appropriate to consider as carbon free is worse than the renewable or small-scale distributed generators.

On the other hand, Al-mulali (2014) estimated a panel mode for nuclear energy consumption in 30 major nuclear-generating countries over the period of 1990 to 2010. The results of the study indicated that nuclear energy consumption has no long-run effect on CO_2 emissions. However, there is negative causal relationship with CO_2 emissions in short run. Based on this result, nuclear energy consumption has been proven to have no effect on CO_2 emissions. Although the relationship between a nuclear energy source and CO_2 emissions has been widely studied by different researchers, this study will also focus on those that explored the relationship between non-renewable electricity source and CO_2 emissions.

Farhani (2015) analysed that non-renewable electricity source has a positive effect on CO_2 emissions in the long run and this issue has been addressed in different countries by several researchers. In another study, Farhani (2014) explored the causal relationship between renewable and non-renewable electricity consumption to CO_2 emissions for the 10 Middle East and North Africa (MENA) countries. It resulted from the bidirectional causality running from non-renewable electricity consumption to CO_2 emissions in long run but unidirectional causality running in short run. Besides, Shafiei and Salim (2014) investigate the relationship between non-renewable electricity consumption and CO_2 emissions in OECD countries. By using the STIRPAT model, there is positive and significant impact of non-renewable energy source on CO_2 emissions from the period of 1980 to 2011.

Additionally, these studies also investigate the relationship between electricity production from non-renewable and nuclear sources on CO_2 emissions by emphasizing the EKC hypothesis. Considering nuclear power generation, Richmond and Kaufmann (2006) examined the relation from EKC hypothesis to CO_2 emissions and then, it also notes that there is limited support for the EKC in the case of OECD countries. It is further supported by the research that is done by

Iwata, Okada and Samreth (2010) where their results discovered a negatively significant effects of nuclear energy on CO_2 emissions as examined from the EKC hypothesis when it took NUC into account in France. Therefore, this article focused on the contribution of further studies by comparing the effects of non-renewable source and nuclear source on CO_2 emissions.

2.2 Review of Relevant Theoretical Models

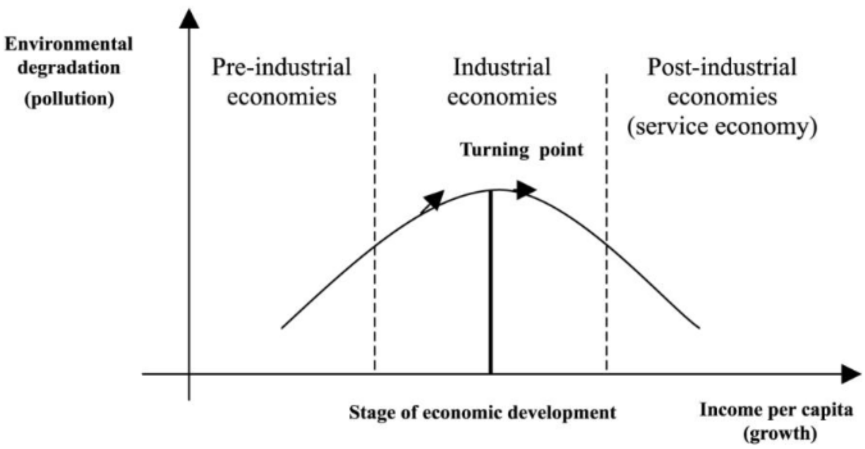
Simon Kuznets is an economist that first found the relationship between national income per capita and the income inequality, EKC hypothesis is an analogy of it. EKC postulates the economic growth and environmental degradation are in the relationship of an inverted U-shaped (Kuznets, 1955). Therefore, EKC hypothesis suggests that when it comes to developing the economy, society may begin to improve the ecological environment and this results in reducing the levels of environmental degradation.

2.3 Proposed Theoretical/ Conceptual Framework

First and foremost, the EKC concept first emerged in the early 1990s with Grossman and Kruger's (1991). World Development Report in 1992 had popularized the EKC theme, which argued that: "The environment is inevitably hurt by the greater view of economic activity such as environmental investments, individual tastes and technology" and "environmental quality will be getting better when the income increases and resources become available for investment".

According to Yandle (2002), EKC hypothesis has an important policy implication. It implies when a country is developing, there will be some environmental degradation until it reaches a certain level of income per capita. The economic growth will undo the damage done in past years and this will be good for the environment. As income per capita rises, the environment worsens, but after a turning point the environment will improve as income per capita continues to rise.

Figure 2.1 Environment Kuznets curve (EKC)

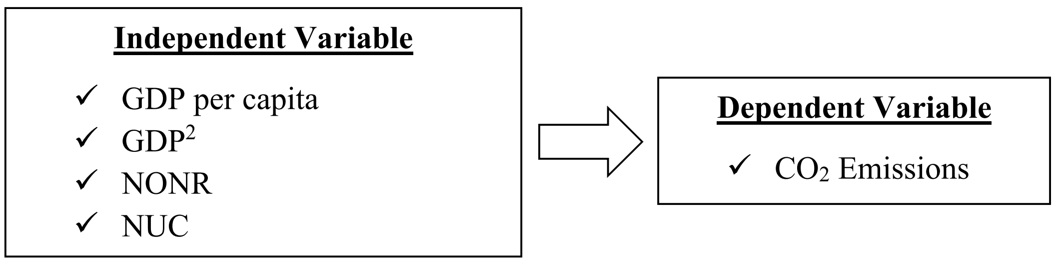


Source: Panayotou, 1993.

Figure 2.1 had shown that at an early stage of economic development, environmental degradation is low due to limited biodegradable wastes and resource base. When economic development speeds up, the advancement from agriculture and other resources to industrialization causes CO_2 emissions to increase and environmental degradation increases due to waste generation. Resources exhaustion exceeds the resource regeneration. At higher stage which is after reaching the turning point, structural changes to service industries with increase in environment awareness and better technology will result in the decline in environmental degradation (Panayotou, 1993).

Shafik (1994), together with Holtz-Eakin and Selden (1995) had concluded that CO_2 emissions were increasing with income per capita. If there are no structural or technological changes in the economy, there will be pollution and other environmental impacts and this is called scale effect. Roberts and Grimes (1997), Schmalensee, Stoker and Judson (1998) found an inverted U-shape relationship in consistence with the EKC hypothesis.

Figure 2.2: Researcher's Model



According to Fethi (n.d.), the sort and capita of non-renewable energy can contribute to enhancing the economic growth, whereas clean energy does not show any effect in long run and short run. There is increasing demand of energy with economic growth and electricity production such as oil gas, coal and nuclear power while nuclear power emit less CO_2 emissions when producing electricity. However, many countries focus more on reducing the gases but less focus in reducing CO_2 emissions when on rapid economic developing period (Iwata, Okada, & Samreth, 2010).

According to Al-mulali (2014), with rising CO_2 emissions encouraging many countries to find another source to meet their keep increasing demand of energy, thus clean energy was found. The result in this journal had shown that the clean energy has a negative relationship with CO_2 emissions in short run but has no relation with CO_2 emissions in long run. Thus, unlike non-renewable energy which will increase the GDP per capita growth and CO_2 emissions, the clean energy will cause less damage to the environment. Nuclear energy will reduce CO_2 emissions in the short and also long run (Apergis et al., 2010).

Using different variables, many researchers had researched their path of testing economic growth and environment pollution nexus. In our study, the non-renewable energy and economic growth will cause more CO_2 emissions and raise environmental degradation in a developing country. After a country has reached a certain level of development, clean energy and continuous increase in the economic growth will reduce the CO_2 emissions, thus it will improve environmental quality.

2.4 Hypotheses Development

Below are the hypotheses of our study:

- **H_1:** CO_2 emissions and GDP per capita are positively related in the short run.
- **H_2:** CO_2 emissions and GDP per capita are negatively related in the long run.
- **H_3:** CO_2 emissions are positively related to NONR in the long run.
- **H_4:** CO_2 emissions are negatively related to NUC in the long run.
- **H_5:** There is directional causality running from GDP, NONR and NUC to CO_2 emissions.
- **H_6:** The EKC hypothesis is valid in 17 nuclear-generating countries.

2.5 Conclusion

This chapter contains the literature review on the dependent variable (CO_2 emissions) and independent variables (GDP per capita, NONR, NUC). The studies of previous researchers on the use of EKC hypothesis and CO_2 emissions are divided, where some studies show validity, some showing validity in the long run, while the others show no validity. When it comes to GDP per capita on CO_2 emissions, studies show that GDP per capita does not solve the problem of CO_2 emissions. There are also arguments that prove a unidirectional causality relationship between CO_2 emissions and GDP per capita, whereby an increase in GDP per capita only increases CO_2 emissions levels. NONR shows a decisive effect on CO_2 emissions in the long run. Other studies show a unidirectional causality in the short run, and in the long run, bidirectional causality. Studies done by past researchers on NUC provide evidence that there is negative relationship on CO_2 emissions, in the long and short run. However, when it comes to using the EKC hypothesis for NUC and CO_2 emissions, there is limited evidence to support it.

Chapter 2 also extensively reviewed the proposed theoretical model used for our study, the EKC hypothesis, because it was used to test relationships between environmental deterioration and GDP per capita. To confirm the statements in the literature review and the significance of the objective in Chapter 1, an empirical analysis will be conducted in the next chapter. Chapter 3 will determine if the findings of our research match the results of previous researches discussed in the literature review. The methodology used will be further studied in Chapter 3.

CHAPTER 3: METHODOLOGY

3.0 Introduction

This chapter introduces the theoretical framework and economic model by focusing the relationship between the CO_2 emissions and GDP per capita, GDP^2, NONR and NUC. Besides, this chapter also describes how the research will be carried out in terms of the research design, data collection, data description and methods of data processing. In addition, the overview of the research methodology in this study will be further explained.

3.1 Theoretical Framework

From the EKC hypothesis, it is plausible to formulate the following relationship:

$$CO_2 = f\ (\underset{+}{GDP},\ \underset{-}{GDP^2})$$

Based on the hypothesis, when a country has low levels of development, CO_2 emissions increase due to limited usage of renewable source. However, CO_2 emissions will further increase as economic development accelerates. At higher levels of development, CO_2 emissions will decrease due to structural changes towards the information-intensive industry with high technology (Panayotou, 1993). Thus, the CO_2 emissions' function postulates an inverted U-shape which is indicated by the positive sign of GDP per capita and negative sign of GDP^2.

$$CO_2 = f\ (\underset{+}{GDP},\ \underset{-}{GDP^2},\ \underset{+}{NONR})$$

According to the Fethi (n.d.), non-renewable energy such as oil, gas and coal lead to enhancement in economic growth and will cause to increase the CO_2 emissions. Besides that, more output of the adoption of non-renewable source will further accelerate the consumption use of non-renewable source leading to more CO_2 emissions. This shows that the NONR has a negative effect with economic growth and has positive relationship with CO_2 emissions in long run. To decrease the CO_2 emissions, we use the NUC as the hypothesis below:

$$CO_2 = f\,(\underset{+}{GDP},\ \underset{-}{GDP^2},\ \underset{+}{NONR},\ \underset{-}{NUC})$$

Nuclear energy source plays an important role to reduce CO_2 emissions and has negative relationship with CO_2 emissions (Baek & Pride, 2014). The causality tests had evidence that NUC to CO_2 emissions had unidirectional causality relationship and the role of NONR in reducing CO_2 emissions. Thus, according to Iwata, Okada and Samreth (2010), the effects of NUC on CO_2 emissions are significantly negative in short run and long run.

3.2 Model Specification

This study proposed an econometric regression to examine the long run relationship between CO_2 emissions (dependent variable) and GDP per capita, GDP^2, NONR and NUC (independent variables). They are specified as follow:

$$CO_2 = f\,(GDP, GDP^2, NONR, NUC) \tag{1}$$

$$CO_{2_{it}} = \beta_{0i} + \beta_1\,GDP_{it} + \beta_2\,GDP^2{}_{it} + \varepsilon_{it} \tag{2}$$

$$CO_{2_{it}} = \beta_{3i} + \beta_4 GDP_{it} + \beta_5\,GDP^2{}_{it} + \beta_6 NONR_{it} + \beta_7 NUC_{it} + \varepsilon_{it} \tag{3}$$

Where CO_2 represents CO_2 emissions, GDP per capita and GDP^2 are gross domestic product and gross domestic product squared, NONR refers to non-renewable electricity production, NUC is nuclear electricity production and ε is error term. β_{0i} and β_{3i} are intercept and β_1, β_2, β_4, β_5, β_6, and β_7 are parameters to be estimated. i denotes the country and t denotes the time period.

Since all data for the variables are in different measurements such as dollar form, percentage and metric tons per capita, we transformed the variables into natural logarithmic form for the purpose to reduce the skewness of data and increase the normality of the distribution, to make an interpretable result.

$$lnCO_{2_{it}} = \beta_{8i} + \beta_9\, lnGDP_{it} + \beta_{10}\, lnGDP^2{}_{,it} + \beta_{11} lnNONR_{it} + \beta_{12} lnNUC_{it} + \varepsilon_{it} \quad (4)$$

Where $lnCO_2$ is natural log of carbon dioxide emissions, $lnGDP$ and $lnGDP^2$ are natural log of gross domestic product and gross domestic product squared, $lnNONR$ refers to natural log of non-renewable electricity production, $lnNUC$ is natural log of nuclear electricity production and ε is regression error term. β_{8i} is intercept and β_9, β_{10}, β_{11} and β_{12} are parameters to be estimated. i denotes the country and t denotes the time period.

Eq. (2) is the common EKC framework with the GDP per capita and GDP squared variables. Eq. (3) is the new inspection to take into account the NONR together with NUC as indicator into the EKC framework. In an attempt to separate estimation is to investigate the common EKC framework and the effects of non-renewable and nuclear sources in this nexus.

From Eq. (3), as given the existence of EKC hypothesis, it is expected that β_4 has a positive sign as a country develops in early stages of development and leads to increase in GDP per capita and then CO_2 emissions. However, when the country develops further, CO_2 emissions will reach a certain level and start to decrease as high income levels and economic growth leads to environmental improvement (Özokcu & Özdemir, 2017). β_5 should be negative. Besides, the expected sign of β_6 should be positive because NONR will lead CO_2 emissions increase, whereas when replaced by NUC, CO_2 emissions will decrease in the future.

The data is collected for all 17 major nuclear-generating countries over the period of 1993 to 2013. Since there have limited data especially on CO_2 emissions and NUC for some countries, this study obtained data starting from the year of 1993 and employed panel analysis to conduct more accurate results.

3.3 Research Design

In this study, quantitative research was employed to achieve the goal to determine the relationship between the explanatory and response variables. Quantitative research is usually present in the form of numerical data, to describe and analyse by using the statistics and test the cause-and-effect of relationships. Research design is determined as a detailed outline of how to construct or study an investigation including data collection methods, what methods will be adopted and how the method will be applied. The aim of this research is to examine the relationship between the CO_2 emissions and GDP per capita, CO_2 emissions and GDP^2, CO_2 emissions and NONR as well as CO_2 emissions and NUC in the top 17 countries over the period of 1993 to 2013. Therefore, all of the data must be collected in numerical form.

3.4 Data Collection

Secondary data were used and panel analysis was utilized to conduct this study. All the data collected were from 1993 to 2013 and from 17 countries that generates nuclear, accounted for 357 observations. The countries involved USA, France, Russia, South Korea, Germany, China, Canada, Ukraine, UK, Sweden, Spain, Belgium, India, Czech Republic, Switzerland, Finland and Japan. Furthermore, this study has collected the CO_2 emissions as dependent variable and GDP per capita, GDP^2, NONR and NUC as independent variables to find the causality relationship between them. All data were retrieved from a reliable database known as World Development Indicators (WDI) from World Bank.

Table 3.4: Variables & Source

Variables	**Indicator name**	**Unit Measurement**	**Source**
Carbon Dioxide emissions	CO_2	metric tons per capita	WDI, World Bank
Gross Domestic Growth per capita	GDP per capita	current US$	WDI, World Bank
Non-renewables electricity production	NONR	% of total electricity production	WDI, World Bank
Nuclear electricity production	NUC	% of total electricity production	WDI, World Bank

Source: WDI, 2017.

3.5 Data Description

3.5.1 Carbon Dioxide Emissions (CO_2 emissions)

CO_2 emissions are present in the environment due to the fossil fuels burning and the production of cement. Besides that, CO_2 emissions are also emitted when solid, liquid and gas fuels as well as gas flaring is used. CO_2 emissions are chosen as the dependent variable for this study because it is a crucial factor to indicate a country's environmental standards. CO_2 emissions are one of the greenhouse gases, a phenomenon plaguing the world in recent times. While there are other indicators like nitrous oxide and methane emissions that can be obtained from the World Bank, CO_2 emissions have the largest percentage that makes up the greenhouse gases.

3.5.2 Gross Domestic Growth (GDP) per capita

According to the details in World Bank (2017), GDP per capita is the division of GDP per capita and midyear population of a country. GDP per capita is the total gross value of all resident producers in the economy, including product taxes, but excluding any subsidies that are not included in the value of the product. To put it simply, it is the sum of monetary value of the final products and services produced in a country, within a certain time period. GDP per capita is important to determine the health of the economy, by analysing the business activities and productivity levels of a country. The result of GDP per capita is more accurate. This is because when population of a country rises, so does the GDP per capita. Therefore, it is appropriate to use GDP per capita as an indicator since it takes into account the population of a country.

According to our topic of study regarding the emission of CO_2, there are studies that show a relationship between CO_2 emissions and GDP per capita, which can be tested using the EKC hypothesis. This curve shows that deterioration of the environment is present in the early stages of economic growth. Therefore, using GDP per capita in our study will help policy makers of a country to find a balance between economic growth and pollution levels.

3.5.3 Non-Renewable Electricity Production (NONR)

Oil, gas and coal sources are known as fossil fuel or non-renewable sources, and they are used to produce electricity. Oil is crude oil and petroleum products. Gas means natural gas, but not in liquid form. Coal refers to all coal and brown coal, which is primary fuel and derived fuels. Peat is included in the category of non-renewable sources. According to the Royal Horticultural Society, peat is made up of plant remains that are not fully decomposed, like grass and moss.

The fossil fuels mentioned are burned to generate energy and the consequence of the burning process is the increase of carbon dioxide in the air. The energy obtained from fossil fuel burning is mainly used for electricity production. That is the reason electricity production from oil, gas and coal sources is used as an indicator for our study. There is evidence suggesting that in the long run, a rise in the CO_2 emissions levels is caused by the continuous usage of non-renewable sources (Jebli &Youssef, 2015). In order to find a solution to reduce the CO_2 emissions levels from electricity production in the environment, it is better to use data that groups together oil, gas and coal sources, instead of using individual energy source.

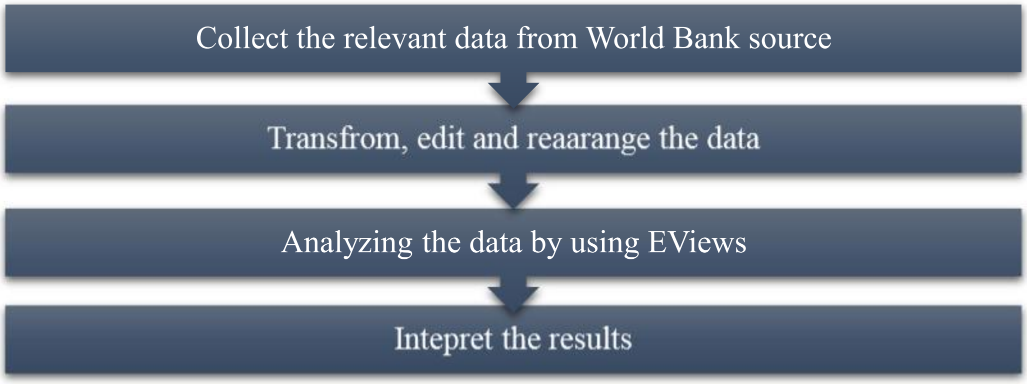
3.5.4 Nuclear Electricity Production (NUC)

The mentioned indicator uses nuclear sources to generate electricity. Nuclear power is the production of electricity by nuclear power plants. When countries needed a solution to reduce the usage of fossil fuels to decrease CO_2 emissions, nuclear capacity grew. There are other choices of renewable energy for electricity production like hydroelectric sources and combined renewable sources. But nuclear energy was chosen as an indicator for this study as it is a clean-air source of energy, it does not release any greenhouse gases and it is able to produce electricity every day, around the clock. According to the Nuclear Energy Institute (2017), a tiny uranium pellet has the exact amount of energy as 149 gallons of oil, 17000 cubic feet of gas, and 1780 pounds of coal. This comparison makes this indicator suitable for the study as able to compare in further details the effects of NONR and NUC on CO_2 emissions.

3.6 Data Processing

The study includes a few steps in the data processing. It is started by obtaining the relevant data in this study. The data for dependent and independent variables includes CO_2 emissions, GDP per capita, NONR and NUC are collected from the available resources such as World Bank Indicator. Secondly, extracted all relevant data from World Bank into Microsoft Excel in a useable manner and then transformed them into the logarithm form. After that, used the useable variable with the log form to run empirical tests by using the statistical tool – EViews 9 programming. Thus, analyse and interpret the results and findings based on the methodology that the study have test subjected to the objective and hypothesis.

Steps in Data Processing



3.7 Methodology

3.7.1 Panel Unit Root Test

Panel unit root test are derived from time series unit root test. The main difference to unit root test of time series analysis is that we have to take into consideration the asymptotic behaviour of the time-series dimension, T and the cross-sectional dimension, N. In most of the panel analysis, the empirical analysis always starts with the unit root test to see if a series is stationary. If a series is non-stationary, it will provide a misleading result which is known as spurious regression. Spurious regression is a familiar and common problem that can found in the time series analysis. The properties of the variables must be tested for the stationary and differencing it to become stationary if they are non-stationary, so as to avoid for getting a spurious regression.

In this study, we used three types of panel unit root test where are Levin-Lin-Chu Test (2002), Im-Pesaran-Shin (2003) test and Maddala-Wu (1999) test. The null hypotheses of these three tests are each time series contain a unit root (non-stationary), whereas alternative hypothesis for the tests is defined as no unit root for each time series (stationary).

Furthermore, the Augmented Dickey-Fuller (ADF) for each cross-section on the equation by Levin-Lin-Chu (LLC) test is written as:

$$\Delta Y_{it} = \alpha y_{it-1} + \sum_{k=1}^{pi} \beta_{ik} \, \Delta y_{it-k} + \gamma_{it} \, \delta + \varepsilon_{it} \tag{5}$$

where α = p – 1, but allow the lag order for the difference terms, ρ_i to vary across cross-section. The testing of LLC derives estimates of α from proxies for $\Delta Y_{it}$and Y_{it} which are standardized, no autocorrelation and deterministic components.

By allowing the lag order for difference terms, the estimation begins with two additional equations by regressing both $\Delta Y_{it}$and Y_{it-1} on the lag termΔy_{it-k}, where for k = 1,…., ρ_i, and independent variable γ_{it}. The estimated coefficients from these two regressions are denoted as ($\hat{\beta}$,$\hat{\delta}$) and ($\dot{\beta}$,$\dot{\delta}$) respectively. By taking ΔY_{it} to define $\Delta \overline{Y}_{it}$ and eliminating the autocorrelations and deterministic components using the equation (5) of first set of estimate:

$$\Delta \overline{Y}_{it} = \Delta Y_{it} - \sum_{k=1}^{pi} \hat{\beta}_{ik} \, \Delta y_{it-k} - \gamma_{it} \, \delta \tag{6}$$

Likewise, the defined $\Delta \overline{Y}_{it-1}$ using second set of coefficients from equation (6) is written as:

$$\overline{Y}_{it-1} = Y_{it} - \sum_{k=1}^{pi} \hat{\beta}_{ik} \, \Delta y_{it-k} - \gamma_{it} \, \dot{\delta} \tag{7}$$

In addition, an estimated coefficient α will be derived from the pooled proxy equation as following equation:

$$\Delta \overline{Y}_{it} = \alpha \overline{Y}_{it-1} + \pi_{it} \tag{8}$$

LLC showed that under the null, a modified t-statistic for the resulting $\widehat{\propto}$ is asymptotically normally distributed:

$$t_{\propto} * = \frac{t_{\propto} - (N\,T) S_N \hat{\sigma}^{-2} \, \widehat{(\alpha)} \mu_{m\tilde{T}} *}{\sigma_{m\tilde{T}} *} \rightarrow \text{N (0,1)} \tag{9}$$

where $t_{\propto}$ is the standard t-statistic for $\widehat{\propto}= 0$, $\widehat{\sigma}^2$, the estimated variance of the error term π, se ($\widehat{\propto}$) is the standard error of$\widehat{\propto}$, and:

$$\breve{T} = T - (\sum_{i} p_i \,/\, N) - 1 \qquad (10)$$

where S_N is the average standard deviation ratio and is known as the ratios of the long-run standard deviation to the innovation standard deviation for each cross section, *i*. This estimation is based on kernel-based techniques and the both term of $\mu_{m\breve{T}}$ * and $\sigma_{m\tilde{T}}$ * are adjustment terms for both mean and standard deviation.

$$Y_{it} = \alpha_i + \rho_i y_{it-1} + \varepsilon_{it} \qquad (11)$$

This is the model of Im-Pesaran-Shin (IPS).

The IPS test is different from LLC test as LLC is more restrictive than IPS because the null hypothesis requires all individual follow a unit root process. Alternative hypothesis allows some individual to have unit roots. This is one of the ways to combine the individual unit root test to derive a panel based result. The IPS test begins with a separate ADF regression for each individual, which is similar with the equation (5):

$$\Delta Y_{it} = \alpha y_{it-1} + \sum_{k=1}^{pi} \beta_{ik}\, \Delta y_{it-k} + \gamma_{it}\, \delta + \varepsilon_{it} \qquad (12)$$

After the regression has been estimated, the average t-statistic for $\propto_{i,}$ from the individual ADF regression, t_{iT_i}(pi):

$$\overline{t}_{\mathrm{NT}} = \left(\sum_{i=1}^{N} t_{IT_i}\,(\mathrm{p}_i) \right) / \mathrm{N} \qquad (13)$$

is then modified to reach a desired test statistic. When the $t_{iT}(p_i)$ is the test-statistic for individual to test the null hypothesis $p_i = 0$ for all i, IPS provided simulated critical values for $\bar{t}_{NT}$ across different number of cross sections N, series length T, and for the equations either with intercept, or intercept, or intercept and linear trend.

Moreover, if the lag order from equation (5) or (12) could be non-zero for some cross section, IPS would show a properly standardized $\bar{t}_{NT}$ which has an asymptotically N (0, 1) distributed as follows:

$$W_{\bar{t}}NT = \frac{\sqrt{N}\left[\bar{t}_{NT} - N^{-1}\sum_{i=1}^{N} E\left(\bar{t}_{iT}(p_i)\right)\right]}{\sqrt{N^{-1}\sum_{i=1}^{N} Var\left(\left(\bar{t}_{iT}(p_i)\right)\right.}} \rightarrow \mathrm{N}\ (0,1) \tag{14}$$

Maddala and Wu (MW) proposed a Fisher-type test that is based on combining the p-values of the test-statistic for a unit root in each residual cross-section i. The test is asymptotically chi-square distributed with 2N degrees of freedom, where N is the number of cross sectional unit, ($T_i \rightarrow \infty$ for finite N). There is an advantage for the test over the IPS test as it can manage the unbalanced panels and allow different lag lengths for the individual ADF tests. The H_0 and H_1 are similar with IPS test. MW test is better than the IPS test with the Monte Carlo simulations.

3.7.2 Panel Co-Integration Test

According to the panel unit root tests above, the long-run equilibrium relationships among non-stationary variables exist if they are integrated at the same order I (1). Several tests can be proposed by panel co-integration like Pedroni (1999; 2004) and Kao (1999) tests. They are based on Engle-Granger (1987) co-integration tests that determine whether a co-integrating relationship exists as to examine the residuals of a spurious regression performed using I (1). In other words, if the residuals are at the order I (0), the variables are said to be co-integrated, otherwise, the residuals will be I (1). They must be at same order if co-integrating relationship exists.

Pedroni and Kao further extended the Engle-Granger framework to test for the co-integration that involves panel data. Pedroni had proposed four panel statistics and three group panel statistics for co-integration to test the hypothesis testing with null hypothesis of no co-integration ($H_0: \varepsilon = 0$) against the alternative hypothesis of co-integration ($H_1: \varepsilon < 0$).

Under the condition of panel statistics, the first-order autoregressive term is assumed to be the same across different countries (cross sections), while the condition for group panel statistics is that the parameter is allowed to vary over the countries (cross sections). The tests are divided into either within the dimensions (panel tests) or between dimensions (group tests).

Pedroni test allows for heterogeneous intercepts and trend coefficients across cross-sections and considers the regression as below:

$$y_{it} = \alpha_i + \delta_i t + \beta_{1i} x_{2i,t} + \cdots + \beta_{Mi} x_{Mi,t} + \varepsilon_{i,t} \tag{15}$$

for i =1, …, N over time periods t =1, …, T; m=1, …, M; where the variables of y_{it} and x_{it} are assumed to be I (1). Given the null hypothesis of no co-integration, the residual, $\varepsilon_{i,t}$ will also be I (1). The parameter α_i and δ_i are both the individual and deterministic trend effects and may be set as zero in case needed.

The residuals are obtained from equation (14) and used to test whether they are I (1) by running the DF type or ADF type regression:

$$\varepsilon_{it} = p_i \varepsilon_{it-1} + \mu_{it} \tag{16}$$

or

$$\varepsilon_{it} = p_i\varepsilon_{it-1} + \sum_{j=1}^{Pi} \varphi\, ij\Delta\varepsilon_{it-j} + v_{it} \tag{17}$$

for each cross section. The Kao test follows the basic approach as the Pedroni tests, but it specifies cross section specific intercept and homogeneous coefficients in the first stage of regressors.

Kao describe the bivariate regression by follows:

$$Y_{it} = \alpha_i + \beta x_{it} + \varepsilon_{it} \tag{18}$$

for

$$Y_{it} = Y_{it-1} + \mu_{it} \tag{19}$$

$$x_{it} = x_{it-1} + \gamma_{it} \tag{20}$$

for i =1, …, N over time periods t =1, …, T. In general, we may choose to run the first stage regression from equation (15), letting the α_i to be heterogeneous, β_i to be homogeneous across cross-sections, and setting all of the trend coefficients v_i to be zero.

Kao then considers to run either the pooled auxiliary regression,

$$\varepsilon_{it} = p_i\varepsilon_{it-1} + \gamma_{it} \tag{21}$$

or the augmented version of the pooled specification:

$$\varepsilon_{it} = p_i\varepsilon_{it-1} + \sum_{j=1}^{Pi} \varphi ij\, \Delta\varepsilon_{it-j} + v_{it} \tag{22}$$

for each cross section.

3.7.3 Panel Dynamic Ordinary Least Square (DOLS)

Suppose the non-stationary variables exist with co-integration, a panel version of DOLS employed to estimate eq. (2) and eq. (3). The methods of the panel DOLS involves augmenting the panel co-integration regression about its specific lags and leads to eliminate the endogeneity and lagged correlation, which is distinct from another version of Fully Modified Ordinary Least Square (FMOLS).

The DOLS was suggested by Saikkonen (1992) and Stock and Watson (1993) in testing hypotheses about co-integrating vector to panel data. Kao and Chiang (2000) developed the DOLS estimator to panel data set which is known as the pooled DOLS. These DOLS estimators add leads and lags for differenced regressors into the regression as parametric by making corrections toward its serial correlation and endogeneity problem. In the work of Kao and Chiang (2000), they used Monte Carlo simulations studies of their finite sample properties, and some empirical applications and obtained the mixed results for the Ordinary Least Square (OLS) and FMOLS estimators. Since the OLS estimator has a finite and significantly sample bias yet generally the FMOLS estimator is often unable to improve the OLS estimator problem. Thus, they figured out that DOLS estimator is more promising than both estimators in estimating panel co-integration regression.

Kao and Chiang (2000) described the pooled DOLS estimator in which OLS is used to estimate an augmented co-integrating regression:

$$y_{it} = \beta X_{it} + \sum_{j=-qi}^{ri} \Delta X_{it+k}\delta_i + \mu_{it} \tag{23}$$

where y_{it} and $X_{it}$are the data that had eliminated the individual deterministic trends. The short run dynamics coefficients δ_i are allowed to be cross section specific and Q_{it} to be the regressors that are formed by interacting the ΔX_{it+k}terms with cross section dummy variables, and let $W_{it}{}' = (X_{it}{}',\ Z_{it}{}')'$, then the pooled DOLS estimator can be written as follow:

$$\begin{pmatrix}\beta_{DP}\\ \gamma_{DP}\end{pmatrix} = (\sum_{i=1}^{N}\sum_{t=1}^{T} W_{it}\, W_{it}{}')^{-1}(\sum_{i=1}^{N}\sum_{t=1}^{T} W_{it}\, Y_{it}{}') \tag{24}$$

3.7.4 Panel Auto Regressive Distributed Lag (ARDL)

ARDL is used to estimate for a co-integrating relationship and also bounds test for the long-run relationship. In this respect, Persaran and Shin (1999) explored that ARDL models are used to examine co-integrating relationships in long-run between the variables. This model is more rigorous in the samples as they are smaller than the co-integration methods. In addition, the estimated ARDL model has satisfactory goodness of fit and is at the conventional levels of significance.

Initially, the presence of multicollinearity will occur as GDP per capita and GDP^2 are usually paired to specify the inverted U-shaped relationship embedded in the EKC hypothesis. In order to avoid this problem associated in estimating data and causing the large standard errors in the result, ARDL is employed to estimate both long run and short run dynamics among all variables. If the short-run elasticity is larger than long-run elasticity, the output will lead to a reduction of pollution over the period. This concern will also motivate the use of an appropriate estimation method as ARDL framework have been applied in the process of a sufficient number of lags. This application is used to capture the data generating process, which included the lags of all variables, therefore, the problem of multicollinearity is minimized (Cerdeira Bento & Moutinho, 2016).

3.7.5 Panel Dumitrescu-Hurlin Granger Causality

Granger causality is the correlation does not necessarily imply causation in any sensible way of that word. Granger causality has become a fundamental tool to examine the causal effect between the variable and also provides the functional connectivity from numerous temporal data that is easily accessible today (Luo, Ge, & Feng, 2011). Based on Dumitrescu-Hurlin (2012) studies, it makes an extreme opposite assumption and allows all the coefficients to be different across cross-sections:

$$\alpha_{0,i} \neq \alpha_{0,k}, \alpha_{1,i} \neq \alpha_{1,k}, \ldots, \alpha_{l,i} \neq \alpha_{l,k}, \forall_{i,k} \tag{25}$$

$$\beta_{0,i} = \beta_{0,k}, \beta_{1,i} = \beta_{1,k}, \ldots, \beta_{l,i} \neq \alpha_{l,k}, \forall_{i,k} \tag{26}$$

In this test, each cross-section is performed by simply running standard Granger Causality regressions. Then, the average of the test statistics, which are termed the W-bar statistic are used to process in to next step. They show that the standardized version of this statistic, appropriately weighted in unbalanced panels and followed by a standard normal distribution which are termed the Z-bar statistic.

3.8 Conclusion

From this chapter, through the data collected, processed and also methodologies, a deeper understanding of the concept was obtained for this study. The methodologies explained includes panel unit root test, panel co-integration test, panel DOLS test, panel ARDL test, and panel Dumitresu-Hurlin Granger causality test. These tests can be used to find out the effect of GDP per capita, NONR and NUC on CO_2 emissions. The methodology that we had discussed will be carried out in the following chapter, where the empirical result will be presented and interpreted clearly.

CHAPTER 4: DATA ANALYSIS

4.0 Introduction

Several panel data approach that was discussed in Chapter 3 are being employed to estimate the panel regression model. Therefore, all of the empirical results obtained from the Eview 9.0 programming will be reported in this chapter. First and foremost, descriptive analysis has been run to ensure no missing data among the 17 major nuclear-generating countries. Panel unit root test is carried out to see whether it is stationary among all variables. Besides, panel co-integration tests are used to examine the long term relationship among the variables, followed by the panel DOLS and panel ARDL that will be employed to interpret both short and long-run estimation among all variables. Lastly, panel Dumitrescu-Hurlin Granger causality test is to identify the direction or bi-direction relationship between the variables.

4.1 Results and interpretations

4.1.1 Descriptive Statistics

Table 4.1.1 Descriptive Statistics

Variables	Observations	Mean	Standard Deviation	Minimum	Maximum
CO_2	357	2.042615	0.641838	-0.244854	3.006060
GDP	357	9.603410	1.394058	5.728186	11.38512
GDP^2	357	94.16345	24.39220	129.6210	32.81211
NONR	357	3.537947	1.135122	0.199635	4.439927
NUC	357	3.057828	1.037749	-1.653823	4.375823

Note: CO_2 stands for log of CO_2 emissions in metric ton per capita, GDP stands for log GDP per capita, GDP^2 stands for squares of log GDP per capital, NONR stands for log non-renewable electricity production in percentages of electricity production and NUC indicates nuclear electricity production in percentages of electricity production.

This study based on annual data for 17 major nuclear-generating countries; USA, France, Russia, South Korean, Germany, China, Canada, Ukraine, UK, Sweden, Spain, Belgium, India, Czech Republic, Switzerland, Finland, Japan. All this variables are downloaded from the World Bank's Development Indicators 2017 (World Bank, 2017). Table 4.1.1 above shows the average value, standard deviation, maximum, and minimum values among 17 countries. The means are CO_2 emissions (2.042615), GDP per capita (9.603410), GDP^2 (94.16345), NONR (3.537947) and NUC (3.057828). Standard deviation in CO_2 emissions is 0.641838, followed by GDP per capita (1.394058), GDP^2 (24.39220), NONR (1.135122) and NUC (1.037749).

4.1.2 Panel Unit Root Test

Table 4.1.2 Panel Unit Root Test Result

	LLC		IPS		FISHER ADF	
	Level (Trend & Intercept)	**1st different (Intercept)**	**Level (Trend & Intercept)**	**1st different (Intercept)**	**Level (Trend & Intercept)**	**1st different (Intercept)**
CO_2	-1.02350 (0.1530) (1)	-7.05547** (0.0000) (1)	-0.94049 (0.1735) (0)	-7.71499** (0.0000) (1)	29.6541 (0.6806) (1)	124.222** (0.0000) (1)
GDP	1.3539 (0.9121) (0)	-9.97819** (0.0000) (1)	2.69518 (0.9965) (0)	-7.69587** (0.0000) (1)	12.5493 (0.9997) (0)	122.417 ** (0.0000) (1)
GDP^2	1.31475 (0.9057) (0)	-9.69286** (0.0000) (1)	2.82492 (0.9976) (0)	-7.53267** (0.0000) (1)	12.3255 (0.9998) (0)	120.173 ** (0.0000) (1)
NONR	-1.24385 (0.1068) (1)	-6.15745** (0.0000) (1)	0.32515 (0.6275) (0)	-8.07924** (0.0000) (1)	34.6666 (0.4360) (0)	129.932 ** (0.0000) (1)
NUC	1.45250 (0.9268) (1)	-2.71290** (0.0033) (1)	0.44672 (0.6725) (1)	-18.8506** (0.0000) (1)	32.3166 (0.5503) (1)	124.850** (0.0000) (1)

Note: LLC, IPS and Fisher ADF represent the Levin et al. (2002), Im et al. (2003), Maddala and Wu (1999) for panel unit root tests. ** indicates rejection of the null hypothesis of no-cointegration at 5% of significance level. The figure without bracket is the test statistic value and follow by the bracket is probability value, while the subsequent brackets show the lag length.

Table 4.1.2 summaries the result of the three major panel unit root tests for the series of CO_2, GDP per capita, GDP^2, NONR, NUC variables. Under the Levin et al. (2002), Im et.al (2003) and Maddala and Wu (1999), the null hypothesis presents in the series have a unit root and the alternative hypothesis shows that it has no unit root. Overall, it can be clearly seen that all variables in level form are not stationary, but stationary in the first difference. This also implies that series of all variables reject null hypothesis at integration of order (1). Consequently, it is possible to apply panel co-integration method in order to test for the existence of the stable long-run relation among the variables.

4.1.3 Panel Co-integration Test

Table 4.1.3 Panel Co-integration Test Result

A) Pedroni	
Panel co-integration statistics (within dimension)	
Panel v-statistic	-0.084979 (0.5339)
Panel rho-statistic	-0.962947 (0.1678)
Panel PP-statistic	-4.791145** (0.0000)
Panel ADF-statistic	-6.105656** (0.0000)
Group mean panel co-integration statistics (between-dimension)	
Group rho-statistic	0.649497 (0.7420)
Group PP-statistic	-4.552188** (0.0000)
Group ADF-statistic	-6.659877** (0.0000)
B) Kao	
ADF	1.648358** (0.0496)

Note: Both tests indicated that the null hypothesis of no co-integration for the variables. ** represented that reject null hypothesis at 5% significant. The figure without bracket is the test statistic value and with bracket represented probability value. The lag length is selected automatically based on SIC.

Based on the results in Table 4.1.2, we proceed to the panel co-integration test. The co-integration concept can be defined as two or more economic variables that are systematic and there is long-term co-movement between each other (Yoo, 2006). From the Pedroni tests as reported in Table 4.1.3, we found that there are 4 out of 7 statistics rejecting the null hypothesis of no co-integration at the 5 percent level of significance. This implies that all the variables are co-integrated and a long run relationship exists between each other in multi county panel. Besides, result from Kao tests also shows enough evidence to conclude that all variables are co-integrating at 5 percent level of significance. In short, the conclusion has been made as there exist a strong evidence to show that there is long-run co-integration relationship among the variables in 17 major nuclear-generating countries.

4.1.4 Panel Long Run and Short Run Estimates Test

Table 4.1.4 Estimated Long-run and Short Run Coefficients using the DOLS and ARDL Approach

	DOLS		ARDL	
	Coefficient	**Probability**	**Coefficient**	**Probability**
Long-run estimates :				
lnGDP	0.467369	0.0183**	-0.056138	0.0000**
lnGDP^2	-0.025477	0.0096**	-	-
lnNONR	0.419148	0.0000**	0.415273	0.0000**
lnNUC	-0.221173	0.0004**	-0.056274	0.0379**
Constant	-		1.033720	0.0000**
Short-run estimates:				
Δ lnGDP	-	-	0.197651	0.0003**
Δ lnGDP^2	-	-	-	-
Δ lnNONR	-	-	-0.452502	0.0062**
Δ lnNUC	-	-	0.097172	0.3401
ECT (-1)	-	-	-0.697639	0.0000**

Note: DOLS represents the panel dynamic ordinary least squares method of Saikkonen (1991). ARDL represents Auto Regressive Distributed Lags. Both approaches are used for estimating and testing hypotheses about a cointegrating vector to panel data. ** represented that reject null hypothesis at 5% significant. ECT represents the coefficient of the error correction term.

Table 4.1.4 reported the results of DOLS and ARDL approach for long-run and short run estimates coefficients. Mark and Sul (2003) explored that panel DOLS can provide precise estimates when compare to other regression testing and it is also straightforward to compute the relevant test statistics. The panel DOLS in the above table are testing the hypotheses about the co-integrating vector in panel data as mentioned in section 3.7.3.

In the above results of DOLS, we found that CO_2 and GDP per capita, and CO_2 and NONR have positive relationship between each other at 5 percent significance level. This means that 1 percent increase in GDP per capita and NONR typically lead to an increase of CO_2 emissions to 46.74 percent and 41.91 percent respectively. Besides, there is an adverse relationship between CO_2 emissions and NUC, which means that in long run dynamic, a 1 percent increase in NUC will lead to 22.12 percent decrease of CO_2 at 5 percent level of significance.

From the above result, it also can be clearly seen that variables are significant at 5 percent and have correct expected sign among all variables. The coefficient of GDP per capita is significant and positive while the sign of GDP^2 is negatively presented. This means that after a threshold of income is reached, CO_2 emissions are expected to fall as income increases further. It implies that the relationship existing between CO_2 emissions and GDP per capita is an inverted U-shaped and it is supported by Choi, Cho and Heshmati (2011), Boluk and Mert (2014), Kasmana and Duman (2015).

Besides, DOLS equation could be written as:

$$lnCO_2 = 0.467369\, lnGDP\; - 0.0\,25477 InGDP^2 + 0.419148\, lnNONR \\ - 0.221173 lnNUC$$

As GDP per capita and GDP^2 are highly correlated to each other, in order to prevent this adverse effects of the multicollinearity associated in DOLS, we remove the GDP^2, and use panel ARDL that contains both the long run and short run dynamics. The findings of ARDL model are robust evidence to support the result from DOLS.

Based on the ARDL result above, CO_2 emissions are treated as a dependent variable in long run coefficient. GDP per capita are negatively related to CO_2 at significance level of 5 percent. This means that 1 percent increase in GDP per capita will decrease CO_2 emissions of multicounty panel by 56.14 percent. However, it is raised to 19.76 percent in short run coefficient. It shows that if all country wants to reduce CO_2 emissions, they have to maintain the economic growth in their country or try to find an alternative to control CO_2 emissions (Ahmad & Du, 2017).

Furthermore, the results make sense to the CO_2 emissions and NUC in long run coefficient which is similar as the above results of DOLS test. All country can get lower CO_2 emissions by increasing the NUC. As defined in 1970 Clean Air Act, nuclear plays a major role in overall compliance as it set the standards in order to improve the nation's air quality ("Clean Air - Nuclear Energy Institute", 2017). In other words, the use of the NUC could contribute to countries' environment improvement. In addition, non-renewable electricity source is positively related to CO_2 emissions. This means that 1 percent increase in NONR will raise CO_2 emissions of around 41.53 percent in the long run. This result is able to prove that countries that use more NONR will emit more CO_2 emissions compared to NUC (Cerdeira Bento & Moutinho, 2016).

ECT (-1) is the most important information from ARDL approach, it was negative and significant as -0.697639 presented. This condition indicated that there is a significant long run relation among the variables. This result also shows the equilibrium is stronger when near to -1. From the table, the particular variables has strong causal effect on the dependent variable, the short run also has strong causal effect. This is reported as:

$$\begin{aligned}\Delta lnCO_2 = {} & 0.197651\ \Delta lnGDP - 0.452502\ \Delta lnNONR + 0.097172\ \Delta lnNUC \\ & - 0.697639\ ECT(-1)\end{aligned}$$

In a nutshell, from the above results of DOLS and ARDL, we can conclude that there is long-run co-integration relationships among the variables as the null hypotheses of no co-integration are rejected at 5 percent level of significance.

4.1.5 Panel Dumitrescu-Hurlin Granger Causality Test

Table 4.5 Dumitrescu-Hurlin Granger Causality Test Result

Null hypothesis	Probability	Conclusion
GDP does not homogeneously cause CO_2 CO_2 does not homogeneously cause GDP	0.0000** 0.1613	GDP → CO_2
NONR does not homogeneously cause CO_2 CO_2 does not homogeneously cause NONR	0.0009** 7.E-09**	NONR ↔ CO_2
NUC does not homogeneously cause CO_2 CO_2 does not homogeneously cause NUC	0.6295 0.0005**	CO_2 → NUC
NONR does not homogeneously cause GDP GDP does not homogeneously cause NONR	0.5963 0.0026**	GDP → NONR
NUC does not homogeneously cause GDP GDP does not homogeneously cause NUC	0.5902 0.0053**	GDP → NUC
NUC does not homogeneously cause NONR NONR does not homogeneously cause NUC	0.0005** 0.1270	NUC → NONR

Note: A→B denotes causality running from variable A to variable B; ↔ denotes bidirectional causality. ** indicates rejection of the null hypothesis of no-cointegration at 5% of significance level.

Over the decades, economists have used the past results to predict the future, even though physical causality between CO_2 emissions and GDP per capita, NONR, NUC are not necessarily by the definition of Granger causality. But all these variables are used to forecast the future CO_2 emissions. Table 4.1.5 summarizes the findings of the test as regards to Dumitrescu-Hurlin Granger causality between CO_2 emissions and GDP per capita, GDP^2, NONR and NUC in 17 major nuclear-generating countries. The above results represent the unidirectional and bidirectional relationship between the panel data of all variables.

Considering there is unidirectional causality running from GDP per capita to CO_2 emissions, GDP per capita has a significantly positive impact on CO_2 emissions, while the CO_2 emissions exert the positive influence upon GDP per capita. In conjunction with the output of the DOLS, this shows the evidence of the

Granger causality as GDP per capita has an influence on CO_2 emissions. EKC hypothesis exists among the countries. Besides, there is also unidirectional causality running from GDP per capita to NONR, and also to NUC. Morimoto and Hope (2004) found that only unidirectional causal relationship exists between GDP per capita and electricity generation.

Furthermore, NONR and CO_2 emissions have bidirectional causality to each other, this hypothesis is also known as the feedback hypothesis (Tigcu, Ozturk & Aslan, 2012). This means that both reactions can take place simultaneously as NONR causes CO_2 emissions. However, at the same time CO_2 emissions may also cause NONR. It is supported by the study of Shafiei and Salim (2014), as mentioned in section 2.1.3. Besides, there is unidirectional causality relation between NUC and NONR.

From the table 4.5, we can conclude that there is bidirectional relationship between NONR and CO_2 emissions and unidirectional relationship from GDP per capita to CO_2 emissions, from CO_2 emissions to NUC, from GDP per capita to NONR, from GDP per capita to NUC, from NONR to NUC. The findings are in line with that of many research studies including Dogan, Seker & Bulbul, (2015) and Salahuddin, Alam and Ozturk (2016).Overall, these results are consistent with those from the DOLS estimator as mentioned in table 4.1.4 and also consistent with the argument we have made.

4.2 Conclusion

In a nutshell, the empirical results have clearly shown the relationship among the independent variables toward the CO_2 emissions through the five tests which cover the panel version of unit root test, co-integration test, DOLS test, ARDL test and Granger causality test in this chapter. In chapter 5, the results will be summarized in a summary of statistical analysis. Besides, major findings of the paper, policy implications, limitations and recommendation of the study will be discussed.

Chapter 5: DISCUSSION, CONCLUSION, AND IMPLICATIONS

5.0 Introduction

In this chapter, it focuses on the statistical analyses and also a clear discussion on the major findings. It is mainly to verify the divergence between the expected relations and hypotheses statistical results. Moreover, implications of study that is vital for policy makers will be discussed in this chapter. The problems that we had encountered during the research progress are discussed in limitations of the study. Lastly, recommendations and suggestions for the future researchers will be provided in the last part of this chapter.

5.1 Summary of statistical analysis

The purpose of this research is to study the link between the CO_2 emissions and the independent variables GDP per capita, GDP^2, NONR and NUC. Besides that, this paper seeks to reveal the short run and long run effects between economic growth and CO_2 emissions, using the EKC as well as the causal direction among the variables. This paper is also used to determine the legitimacy of the EKC hypothesis. There were 17 countries used for this research, with all 17 countries generating nuclear energy from the year 1993 to 2013.

The first test that was conducted is the panel unit root tests for all the variables. Most analysis starts with this test in order to determine if the variables are stationary. A non-stationary series will give inaccurate results. Based on the results obtained, the variables were not static in level form. However, in the first difference, the variables were stationary. The test results show that variables reject null hypothesis at integration of order (1).

Once it was cleared that all variables are in static form, it became possible to continue with the panel co-integration method. If there is integration between variables at similar order, there are long-run equilibrium relationships that exist in non-stationary variables. To determine the existence of co-integrating relationships in the long run, tests like Pedroni and Kao tests are carried out. The Pedroni test that was carried out suggests that there was co-integration among all variables and a long run link among each variable. The Kao test provided evidence that there was co-integration at 5 percent significance level, strengthening the conclusion that co-integration is present between the variables.

The research continued with the panel long run and short run estimates test by using DOLS and ARDL approach. The DOLS enhances the panel co-integration regression with specific lags to remove serial correlation and endogeneity. According to the results obtained in this study, at 5 percent significance level, there is a positive relationship between CO_2 emissions and GDP per capita (a 1 percent increase in GDP per capita leads to 46.74 percent increase in CO_2) and between CO_2 emissions and NONR (a 1 percent rise in NONR brings a 41.91 percent rise in CO_2). However, a negative relationship runs between CO_2 emissions and NUC in the long run, where a 1 percent increase in NUC leads to a 22.12 percent in CO_2 emissions at the same significance level. The ARDL is used to investigate the long run relationship and co-integration between variables. At 5 percent significance level, CO_2 emissions and GDP per capita are negatively linked, a 1 percent hike in GDP per capita lowers CO_2 emissions by 56.14 percent but increases emissions by 19.76 percent in the short run. For CO_2 emissions and NUC, the results were similar to that of the DOLS tests. There is a positive relation between CO_2 emissions and NONR, a 1 percent increase in NONR leads to a 41.52 percent increase in CO_2 emissions in the long run. Based on the results obtained, it is concluded that at 5 percent significance level, the null hypotheses of having no co-integration is rejected, proving the presence of long run co-integrated relationships among variables.

The last test performed was the panel Dumitrescu-Hurlin Granger Causality test. This approach is important to examine the causal effect between variables, whether they are unidirectional or bidirectional. From the results of this test, it is proven that there is a bidirectional relationship between CO_2 emissions and NONR, while GDP per capita and CO_2, GDP per capita and NONR, GDP per capita and NUC, CO_2 and NUC, NUC and NONR have unidirectional relationships.

5.2 Discussion of Major Finding

The prime motive in this study is to see how GDP per capita, NUC and NONR affect CO_2 emissions. Besides that, this research is to study the EKC hypothesis in various countries. This study further discusses the empirical results that some researchers have obtained to examine whether the results are similar with the expected results or hypotheses of this study which was mentioned in Chapter 2.

In the short run, researchers expect that GDP per capita have a positive relationship with CO_2 emissions while the GDP^2 showed negative relationship with CO_2 emissions. An increase in the GDP per capita will in turn raise the CO_2 emission levels in the initial stages. This result consistent with their hypothesis as GDP per capita would be positively correlated with CO_2 emissions in the short run while in the long run, GDP per capita is found to reduce the CO_2 emissions.

By applying panel DOLS to conduct the validity of the EKC hypothesis in various countries, this result is consistent with the hypothesis which proves that EKC hypothesis is valid among 17 major nuclear-generating country. It is supported that GDP per capita has a positive relationship with CO_2 emissions while GDP^2

negatively affect CO_2 emissions. To avoid the problem associated with GDP per capita and GDP^2, panel ARDL was employed to solve multicollinearity. The empirical result is further evidence that EKC hypothesis is valid in this study. It can be seen that the increase in GDP per capita will bring the effect of a lower level of pollution in the country over the time.

NONR was found to have a positive relationship with CO_2 emissions. It is support by Fethi (n.d.) as NONR increase will increase CO_2 emissions, thus raise the pollution level. Furthermore, NUC are negatively correlated with CO_2 emissions. This is consistent with the hypothesis and this result explored that if a country invest in NUC, it will potentially reduce the CO_2 emissions in long run. In addition, Iwata, Okada and Samreth (2010) also found that NUC plays an important role in reducing CO_2 emissions.

Lastly, the Dumitrescu-Hurlin Granger causality test was done and causal direction existed among all the variables. The result shows that there are only one bidirectional causality running from NONR to CO_2 emissions while unidirectional causality runs from GDP per capita to CO_2 emissions, GDP per capita to NONR, and GDP per capita to NUC.

5.3 Implication of Study

There is a global impact in emissions of greenhouse gases. Therefore, greenhouse gases should be reduced through individual behaviour either indoors or outdoors. It proves that a low-carbon economy will reduce the country's reliance on imported fossil fuels which might cause higher prices of energy.

In assessing the new and existing business ventures, production of electricity will result in the highest level of emissions of greenhouse gas. Thus, proper policy should be implemented as electricity production caused the greatest environmental impact. Eco-friendly electricity production technology has to be practiced due to combinations of government regulations with high fossil fuel and coal prices. Besides, increased electricity demand is also a reason to encourage the implementation of new electricity production technology. Therefore, it is recommended that acquirement of low-emission renewable energy technologies by production industries are most suitable for electricity production compared to other energy applications. Investment in "clean energy" by policy makers is appropriate instead of making fossil fuels more expensive.

Secondly, policy makers are suggested to carry out the economic aid which primarily comes in two particular forms, carbon tax or a cap-and-trade program. These two forms are the approaches that are most favourable by economists to reduce GHG emissions rather than implementing regulatory approaches. These two forms will charge electricity producers based on the level of carbon emissions which they emit. Under cap-and-trade, policy makers set up a certain limit or "cap" on the overall amount of GHG's. The GHG's mainly consists of carbon dioxide from fossil fuels burned that can be produced each year. By this policy, it would create revenue for the federal government and GDP per capita of countries are therefore increased. A chargeable fee on CO_2 emissions would give an economic incentive to reduce the use of energy. The fees which increase from time to time would motivate businesses to invest in sustainable energy technologies.

Lastly, as this study is mainly emphasizing on nuclear energy, it plays a vital role in providing clean energy to sustain economic development around the entire world. Generally, nuclear energy is categorized as the largest source of clean energy, producing neither greenhouse gases nor air pollutants. Therefore, policy makers are recommended to invest in Nuclear power plants aid compliance with the Clean Air Act of 1970, which set certain standards to improve the countries' air and environmental quality. It gives countries additional flexibility in complying with clean-air requirements by using more nuclear energy,

5.4 Limitation and Recommendation of the Study

During the progress of completing this paper, several limitations have been found. The main problem we have encountered was the limited sources of data available. The inclusion of nuclear sources interacting with electricity production can be considered as a new attempt in this area of research. We have included a total 17 countries to conduct the study. However, since nuclear is still new to certain countries for its alternative replacement of NONR, therefore we are unable to accurately carry out the comparison between countries within a period of time. Specifically, we could only obtain the data regarding the nuclear sources starting from the year 1993 onwards. This limitation will cause researchers to omit possibly important determinants that may be influential and useful to the study. It will eventually end up with inaccuracies in the research. Hence, future researchers are recommended to use alternative sources for the renewable energy with sufficient data available.

Besides, the results obtained in this study only can be used as reference in most of the developed countries as the results may be different if applied in developing countries. For most of the developed countries, they are able to have more nuclear plant, whereas for developing countries they might not be able to equip themselves with NUC. In other words, the pollution level for every country will definitely be different, thus it is confusing while making comparisons. Future researchers are suggested to carry out research in developing countries so that more accurate and reliable results can be obtained.

5.5 Conclusion

As a conclusion, this study has investigated the Unit root test and Granger Causality test to investigate the relationship among all the variables in this paper. The result shows that GDP per capita, GDP^2, NONR and NUC has co-integration (long run) relationship but has no causality (short run) relationship with CO_2 emissions in the countries we conducted for the study. Finally, this paper has met the primary objective in which to examine the causal relationship between all independent variables towards CO_2 emissions.

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