Economic and Social Factors Contributing to CO_2 Emission

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ABSTRACT

This research studies the economic and social factors of carbon emissions in the Organization of Petroleum Exporting Countries (OPEC) over period 1995-2014. More especially the thesis studied the link between CO_2 emissions and four socio-economic variables (per-capita GDP, urbanization, fossil fuel energy consumption and international trade). A long run relationship is confirmed by Kao (1999), Pedroni (1999) and Johansen (Maddala and Wu, 1999) panel cointegration tests. Fully modified ordinary least squares (FMOLS) outcomes specify the following. The relationship among CO_2 emission and GDP is non-linear in OPEC countries, it follows the inverted U-shape suggested by the environmental Kuznets curve hypothesis. Urbanization is responsible for a significant proportion of carbon emissions in OPEC countries. Fossil fuel energy consumption is a significantly positive driver of carbon emission. A large proportion of carbon emissions within OPEC member countries is due to international trade.

Keywords: OPEC**,** Carbon emissions, GDP per-capita, Energy consumption, Urbanization, International trade, FMOLS.

ÖZ

Bu çalışma, 1995-2014 döneminde Petrol İhraç Eden Ülkeler Örgütü'ndeki (OPEC) karbon emisyonlarının ekonomik ve sosyal belirleyicilerini incelemektedir. Bir başka deyişle bu tez karbon emisyonları ile dört sosyo-ekonomik değişken (kişi başına GSYİH, kentleşme, fosil yakıt enerji tüketimi ve uluslararası ticaret) arasındaki denge ilişkisi inceler. Uzun vadeli denge ilişkisi Kao (1999), Pedroni (1999) ve Johansen (Maddala ve Wu, 1999) panel eşbütünleşme testleri ile doğrulanmaktadır. Tamamen değiştirilmiş normal en küçük kareler (FMOLS) sonuçları aşağıdakileri gösterir; Çevresel Kuznets eğrisi hipotezinin önerdiği ters U-şeklini takip eden OPEC ülkelerinde karbon emisyonu ile GSYİH arasındaki ilişki doğrusal değildir. OPEC ülkelerinde karbon salımının önemli bir kısmından şehirleşme sorumludur. Fosil yakıt enerji tüketimi, karbon salınımının önemli bir pozitif etkenidir. OPEC üye ülkelerindeki büyük oranda karbon emisyonu uluslararası ticaretten kaynaklanmaktadır.

Anahtar Kelimeler: OPEC, Karbon emisyonları, Kişi başına GSYİH, Enerji tüketimi, Şehirleşme, Uluslararası ticaret, FMOLS.

DEDICATION

To my family and memory of my father

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

1.1 Background of the Study

Dangerous changes are taking place in the global environment as a result of human activities. The anthropogenic transformation of the environment through human-induced actions such as industrial processes, deforestation, land clearing for agriculture, degradation of soils, and fossil fuel burnings for electricity, transportation, heat and industry is of great concern for two particular reasons related to greenhouse gas (GHG) emissions.

First, it has resulted in dramatic changes to the atmosphere over the indiscriminate emission of greenhouse gases (GHGs) such as CO_2 gas, methane, chlorofluorocarbons and nitrous oxide. In general, GHGs lower the efficiency with which the earth cools itself and distort the radioactive balance of the earth, thereby altering the atmospheric and oceanic temperatures as well as weather patterns (Ephraums and Jenkins, 1992).

Second, it has led to serious changes in the global biosphere. As at 1700, half of the global biosphere was in its natural state while about forty-five percent of it was in a semi-natural condition. However, as at the year 2000, more than half of the biosphere had become human settlements and agricultural land, with only about twenty percent remaining in a semi-natural state and just twenty-five percent retaining its natural state (Vitousek *et al.,* 1997, Harrison and Pearce, 2000; Ellis *et al.,* 2010). This drastic change in the terrestrial biosphere indicates a reduction in the number of trees available to absorb GHGs from the atmosphere. This further raises the level of GHGs in the atmosphere. Trees have as much as three hundred billion tons of carbon stored up in them. This amounts to about forty times the yearly carbon emission from fossil fuels. Not only will fewer trees lead to lower absorption of GHGs from the atmosphere, GHGs stored up in the felled trees will also be released into the atmosphere.

1.2 Statement of the Problem

Karl *et al.* (2009) show that global warming over the past several decades have been due mainly to human-induced increases in GHGs. As a result of GHG emissions, the world is currently experiencing climate change in the form of extreme temperatures (record lows and record highs) in different regions, melting icebergs in both North and South Poles, rising sea levels, temperature-related changes in the bio-habitat of several animal and plant kingdoms, more frequent and more severe tornadoes, droughts and snow falls. Proliferation of GHGs also adversely impact the health determinants such as food supply, water resources and ecological disease control vectors (Richardson *et al.,* 2009). Furthermore, Solomon *et al.* (2009) show that the climate variation which occurs as a result of rises in CO_2 attentiveness is incorrigible to a thousand years later the cessation of emissions.

1.3 Aim of the Study

The climatic implication of GHG emissions has raised public interest in its causes and this increased interest has consequently triggered attempts to understand the factors that induce GHG emissions around the world. The identification of measures capable of lowering carbon emissions has motivated attempts in related literature to reach a consensus on the factors that cause carbon emissions. Research that provides detailed understanding of the determinants of environmental degradation caused by GHG emissions will have important policy implications, as findings from such a study could influence future policy direction. Particularly, the clear identification and efficient management of economic and social factors that lead to carbon emissions can help to achieve a clean development mechanism. Therefore, the main purpose of this study is examination of economic and social determinants of carbon emissions in the Organization of Petroleum Exporting Countries (OPEC).

Although there are various types of GHGs, this study focuses on carbon emissions since it accounts for approximately seventy-six percent of total GHG emissions in the world (IPCC, 2014). Also, the choice of OPEC countries as a case study is linked for the point that some member nations such as Saudi Arabia, Qatar, United Arab Emirates, Kuwait and are ranked in the top ten of countries with highest carbon emissions per population and/or per economic size. This is probably not a coincidence as these oil-producing countries might not place enough emphasis on efficient use of energy sources.

More specifically, this study addresses the following research questions:

1) How do economic factors, such as GDP per capita, energy consumption and trade volume affect CO_2 emissions in OPEC nations?

2) How do social factors, such as urban population size affect carbon dioxide emissions in OPEC countries?

1.4 The Structure of the Study

This research is compiled in six chapters. In the first chapter, the generalities of the research such as the study's background, the problem of statement, the aim and goals of the research, and the questions of study. The second chapter focuses on the theoretical aspects of GDP per capita, urban population, trade openness and energy consumption on the carbon emission. It also presents an overview of the association of Petroleum Exporting Countries. The third chapter provides a review of previous related literature. The fourth chapter gives a detailed explanation of the data used, the model specified and the methodology adopted. The fifth chapter presents the empirical results and their interpretation. In the last chapter, conclusions, suggestions and policy recommendations are provided.

Chapter 2

THEORETICAL BACKGROUND

This research efforts to consider the special impacts of economic also social factors on CO_2 emissions in OPEC countries. Therefore, in this chapter, a brief overview of the study area and insights into related concepts and models are provided.

2.1 Organization of Petroleum Exporting Countries (OPEC): An Overview

OPEC organization is a transnational cartel made up of twelve developing countries and headquartered in Vienna, Austria. The member nations are as follows; Libya, Angola, Venezuela, Ecuador, Algeria, Iran, Qatar, Kuwait, Saudi Arabia, Iraq, Nigeria plus Arab united Emirate. The organization's origin can be traced back to 1960 when it was established in Iraq by the very first set of by members (Venezuela, Kuwait, Iraq, Saudi Arabia also Iran). OPEC as an entity currently accounts for approximately forty-four percent of world oil production and the member countries jointly own approximately eighty-two percent total oil reserves of the world.

The objectives of OPEC are the following; to streamline petroleum policies across member nations, to stabilize oil markets, to achieve efficiency in petroleum supply to consumers, to generate a steady stream of income for production also ensure rational yield on funds' investments on the oil sector (OPEC, 2013).

OPEC as a body is worthy of special attention because of its capability to influence carbon emissions through oil pricing and oil cuts, both in member countries and internationally. When OPEC raises oil prices, demand generally falls and this could consequently lower carbon emissions, whereas when OPEC does the opposite, it could result in increased pollution (Rosnick, 2018). In addition, because of the huge reserves of fossil fuels, energy saving is not taken seriously in OPEC. This has the tendency to cause increases in carbon emissions.

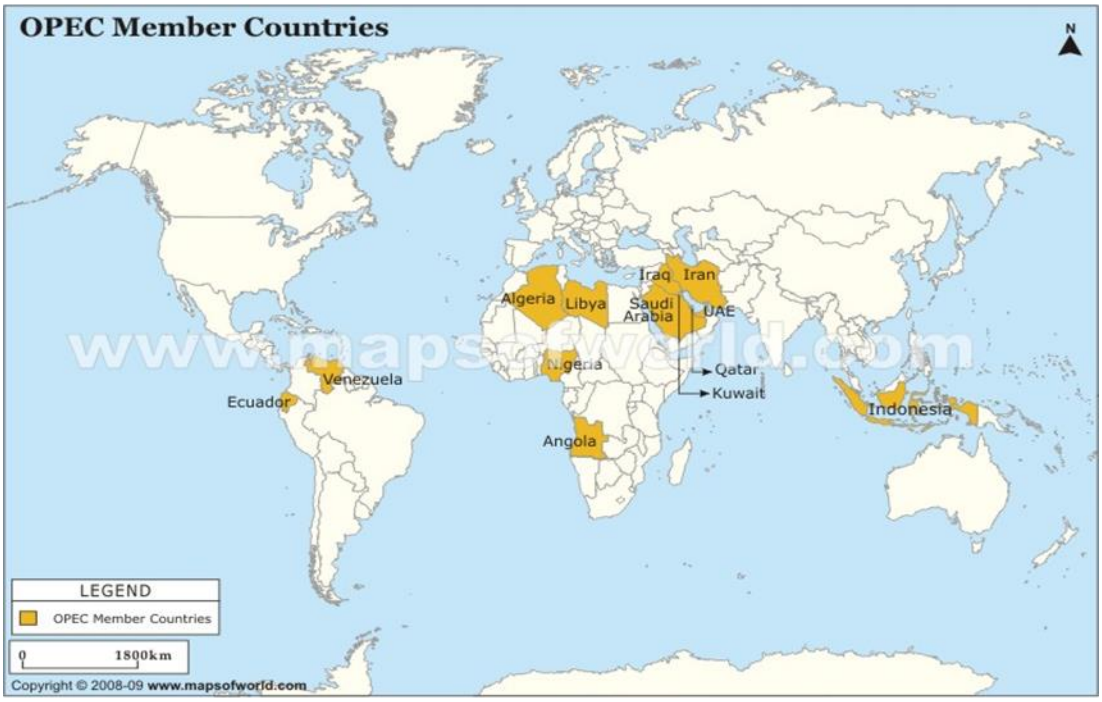

Figure 1. OPEC countries

2.2 Environmental Impact of Economic Factors

The impact of economic activities on the environment has been receiving increasing attention over time. Theoretical channels through which economic activities impact the environment are discussed in this section.

2.2.1 Economic Growth, Carbon Emission and Energy Consumption

It's often suggested that higher economic activities result in higher pollution; after all, usage of fuel is one of the important issue to boost economic for a county (Cerdeira Bento, 2014). In the process of achieving economic growth, large quantities of fossil fuel are burnt, resulting in increased carbon emissions. This linear assumption about the link among growth of economic on the carbon emissions has however been strongly questioned. The greatest popular hypothesis to query this assumption is the environmental Kuznets curve (EKC) hypothesis (Lamla, 2009).

The EKC hypothesis suggests, rather than being linear, it is formed as inverted U shape. One of the reasoning behind this theory is that as nations transit from small level of economy to medium level of growth, economic growth takes precedence over environmental protection. Such countries are thus likely to experience environmental challenges. As countries however carry on to change from middle to high level of expansion, they will change and more concerned about issues of environmental degradation and actively seek ways to achieve environmental sustainability (Gouldson and Murphy, 1997; Mol and Spaargaren, 2000).

Kuznets (1955) was the first to introduce the Kuznets curve hypothesis when he argued that between per capita income and inequality exists the inverted U-shaped relationship. The 1990s witnessed the assimilation of this concept into environmental policy literature. Since then it has continued to be used as a means of studying the link among income per capita and environmental quality. The environmental Kuznets curve hypothesis pioneers include Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992), and Panayotou (1993).

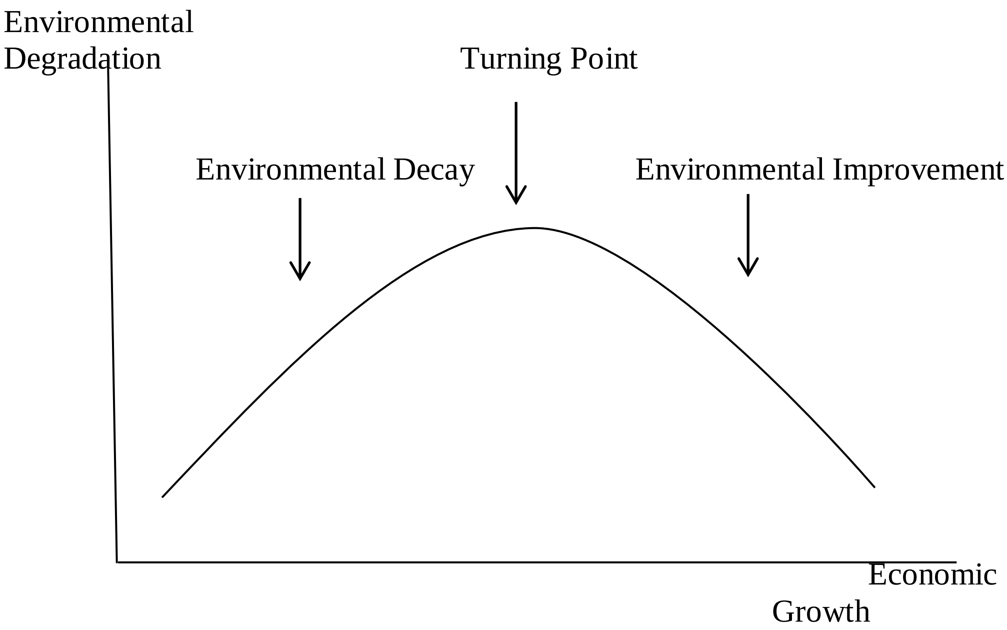

Figure 2. Environmental Kuznets Curve

2.2.2 International Trade as an Important Source of Pollution

Another widely debated issued in the economic activity-pollution nexus is the connection amongst international trade and CO_2 emissions. The goods transportation across international borders is a key channel through which international trade causes pollution. International trade involves the transportation of goods over relatively long distances. This requires the burning of oil, which in turn results in increased pollution. For example, trucks, ships and airplanes are commonly used in transporting goods between countries, and they all burn fossil fuels and release carbon into the atmosphere (Batra *et al.,* 1998).

Projections show that by the year 2050, carbon emissions from international aviation and maritime transport will jointly account for approximately forty percent of global carbon emissions (Cames *et al.,* 2015). In addition, major maritime oil spills are most commonly caused by accidents involving vessels used for transportation of fossil fuels (Gil-Agudelo, 2015). Of the 300 million tons of crude oil shipped around the world annually, about 2 million tons are spilled into the marine environment (Batra *et al.,* 1998).

2.3 Environmental Impact of Social Factors

Changes in urban population is arguably the most important social determinant of pollution. The reason is because urbanization is much more than just population growth and physical expansion of settlements; it has a strong influence on the socio-economic activities of residents (Yang *et al.,* 2016). Urbanization is a demographic factor that affects human behavior by altering the energy consumption pattern of households (Barnes *et al.,* 2010).

There are two common theories directly linking urbanization with the environment—the theory of compact cities and the theory of urban environmental transition. The compact cities theory on one hand posits that when urban density rises, it facilitates the achievement of economies of scale in public infrastructure, and this in turn lowers the damage to the environment (Burton, 2000; Capello and Camagni, 2000). The urban environmental transition theory on the other hand argues that urban settlements become richer through increased manufacturing which often leads to environmental problems in the form of pollution. Furthermore, richer urban settlements create richer residents who demand more energy-intensive products. However, as these urban areas become even richer, environmental pollution may reduce due to better environmental regulations, improved technology and recomposition of the economic makeup (McGranahan, 2010; Sadorsky, 2014).

2.4 Analytic Models for Unraveling Drivers of Environmental Impacts

Several analytic models that accommodate the functional characteristics forms of the interaction across anthropogenic determinants and the environment exist. The most common of such models are described in this section.

2.4.1 The IPAT Model

The IPAT model is an identity that is widely used in examining the environmental impact of human activities (Harrison, 1993; York *et al.,* 2002). Its origin can be traced back to the Holdren-Ehrlich/commoner debate of the early 1970s. While Holdren and Ehrlich (1970) were the prior to introduce related concept and the equation is related, Commoner *et al.* (1971) were the first to apply it in data analysis. The model specifies environmental effects as the multiplicative product of 3 major factors—population, affluence (per capita production or consumption) and technology (York *et al.*, 2003a). The multiplicative nature of the model shows that none of the three determinants can be solely responsible for environmental changes. When the traditional IPAT model is applied in the analyses of carbon emissions, it generally takes the following form:

$$I = PAT \tag{1}$$

Where I represents total emissions, P stands for population, A is GDP per-capita and T mentions as carbon emissions per unit of GDP.

2.4.2 The ImPACT Model

Waggoner and Ausubel (2002) remodified the IPAT model by splitting the T component of the original identity into C and T components, and renamed the new model ImPACT. The motive of the authors was to specify the determinants which will be altered the reduction environmental effects. The ImPACT model indicates the total carbon emissions is a function of the product of population (P), GDP per-capita (A), energy consumption per unit of GDP (C) and carbon emissions per unit of energy consumption (T). It is specified as follows:

$$I = PACT \quad (2)$$

2.4.3 The IPBAT Model

Schulze (2002), in an attempt to account for additional determinants of environmental impacts, also extended the IPAT model in another direction. He made a case for the environmental impact of behavioural choices. According to him, behavioural choices may influence the following; use of efficient devices, ecological restriction efforts, whether investments will be made in fossil fuels with high CO_2-to-energy content such as coal. In line with Schulze's (2002) claims, a new identity was specified as follows;

$$I=PBAT \quad (3)$$

Where B represents behavioural choices.

The main strength of the aforementioned models (IPAT, ImPACT and IPBAT) is that they are simple and relatively parsimonious specifications of the determinants of environmental change (York *et al.*, 2003b). The models however have certain weaknesses. First, due to their nature as mathematical identities, it is not possible to carry out hypothesis testing with them. Second, they are based on the assumption of proportionality in the functional relationships such that the doubling of one of the determinants will result in the doubling of the environmental impact. In other words, the models cannot accommodate non-proportional or non-monotonic effects (Dietz and Rosa, 1994; Rosa and Dietz, 1998).

2.4.4 The STIRAT Model

Due to the weaknesses identified in the previous models, Dietz and Rosa (1994) modified the mathematical identity (IPAT) in stochastic model commonly referred to as stochastic effects by Regression on Population, Affluence and Technology (STIRPAT). The STIRPAT model is suitable for empirically hypotheses testing. Moreover, this model is well able to accommodate different practical methods. For instance, polynomial version or quadratic of affluence may be easily involved in the model to test the EKC hypothesis. Another key advantage of STIRPAT is that it permits once to check different determinants by explicitly including all of them as regressors in the simple model (York *et al.*, 2003b). The STIRPAT model is specified thus:

$$I_i = aP_i^b A_i^c T_i^d e_i \quad (4)$$

Where a is the constant, b, c and d are the exponents of P, A and T to be assessed, e is the error term and i represents the observational units.

Equation (4) may be alternatively written in an additive logarithmic form as:

$$logI_i = a + blogP_i + clogA_i + dlogT_i + e_i \quad (5)$$

Chapter 3

LITERATURE REVIEW

The objective of identifying the measures capable of lowering carbon emissions has motivated attempts in related literature to reach a consensus on the factors that cause carbon emissions. Extant environmental policy literature is thus substantially focused on defining the relationship between pollution and socio-economic factors. Some of such studies are reviewed in this section.

Grossman and Kreuger (1991) were the first to discover the inverted U-shaped association among pollution and income per capita. They conducted a research to examine the impacts of environment on North American agreement of Free Trade and examined the link among, pollution trade and economic growth. In their research, they used the GDP per capita variable, time trends and pollution indicators such as emissions of sulfur dioxide. Specifically, they found that the relationship among GDP per capita and emission of sulfur dioxide has a U-shaped relationship turned upside down.

Shaw and Hung (2004) found out the bilateral link amongst economic growth and weather pollution in Taiwan. They employed two-equation simultaneous models to control for possible endogeneity in the relationship. The authors concluded that while economic growth impacts pollution, there is no evidence that various types of pollution impact economic growth. They also confirmed the EKC theory in the link among pollution and economic growth.

Paul and Bhattacharya (2004), in their study, identified several elements which impact the variations in the level of related-energy carbon exodus. They analyzed four elements affecting carbon emissions (contamination coefficient, economic activity, structural changes and energy intensity) by applying a complete technique of analyzing to Indian data for the period 1980-1996. Their findings were as follows; growth of economic has the greatest affirmative impact on the changing in carbon emissions in total parts of the Indian economy, a decreasing trend is noticeable in carbon emissions from the industrial and transport sectors because of using energy and fuel in efficiently, the lowering impact of the energy intensity and coefficient pollution on carbon releases is practically non-existent in the agricultural sector.

Frankl and Rose (2005) studied the effect of trade on the environment at a certain level per capita gross domestic product, and concluded that more trade would lead to more production and eventually increased pollution. In their study, they also concluded that there are significant exogenous factors other than GDP per capita that affect the environment such as the degree of democracy and population density. The results of this study confirmed the EKC hypothesis that economic growth worsens the status of the environment at lower income levels and improves at high levels of income.

Ramanathan (2005) analyzed the interaction between carbon dioxide emissions and energy consumption of MENA countries using documents envelopment examination. In this study, changes in the energy efficiency of countries were also estimated via the Malmqvist productivity index for the period 1996-1992. The findings indicated that under constant returns to scale assumption, Bahrain, Oman and Sudan are proficient countries, while Saudi Arabia is the most inefficient. Whereas, below the variable assumption of returns to scale, Israel and Mauritania are also proficient.

Golub, Markandya and Pedroso-Galinato (2006) studied the relationship among income per capita and pollution caused by carbon emissions in 12 Western European nations over a 150-year of time. Their findings indicated that the inverse U-relation among income per capita and pollution suggested by the EKC theory exists in most of the countries.

Soytas, Sari & Ewing, (2007) discovered the impact of carbon emission and energy consumption in the United States in a study entitled "US Income and Energy Consumption and Publication in the United States." The authors examine the causal link among energy consumption, income and carbon emissions in a model that includes human capital and gross capital formation for the period 1960-2005, the authors found that in the long run income in the United States does not granger comes dioxide carbon emissions, nevertheless energy consumption has such a relationship. Therefore, growth of revenue itself cannot be an answer to problems of environmental.

Ang (2007) investigated the dynamic causal relationships between the energy consumption, emission of pollutants and total production of France via vector correction and collective error modeling techniques over the period 1960 - 2006. He claimed that the variables are dependent to each other and, therefore, their relationship should be tested and via a combined basis. His further discovered that the long-term relationship between these variables is relatively strong. The causal relationships showed that growth of economic has a causal effect on consumption of energy growth also long-term pollution growth. His finding also confirmed only a way of causal correlation between the energy consumption growth plus short-term production growth.

Azhar, Khalil and Ahmed (2007) studied the effects of commercial liberalization on the amount of air and water pollution in Pakistan during the years 1972-2001 using the Johansen-Juselius convergence method. In this study, in order to show the effects of commercial liberalization on air and water pollution indicators, the degree of openness of trade, which is definite as trade volume ratio to GDP, is used. The conclusion reached by this study is that increasing the degree of openness of trade causes to a rise in climate pollution, and the rise of gross domestic product as a variable of scale has a negative effect on environmental quality indicators.

Halicioghlu (2009) conducted a study to examine the dynamic stochastic relations among income, carbon emissions and foreign trade in Turkey between the year of 1960-2005 using both the ARDL and augmented Granger causality techniques. This research shows the existence of two kinds long-term relationship among variables. In the first form of long-term relations, CO_2 emissions are specified by energy using, foreign trade and income. In the next form, the long-term relationship income is specified by energy use, CO_2 emissions and foreign trade. The empirical results further show that in terms of ability to explain turkey's CO_2 emission, income comes first, traced by consumption of energy and then openness of trade.

Tunç, Türüt-Aşık and Akbostancı (2009) analysed the elements which influence variations in carbon releases in the economics of Turkish. This examination was carried out with the aid of the Log Mean Divisia Index (LMDI) methodology, using data from 1970 to 2006. They divided the economy in three major areas (industry, services and agriculture) and energy resources in four sections (petroleum, solid fuels, electricity and natural gas) and claimed that the major factor of variations in CO_2 emissions is economic activity.

Zhang, Mu and Ning (2009) analyzed the energy-related carbon emission in China, using decomposition analysis. They used the Laspires decomposition approach to examine the nature of the four factors affecting carbon emissions for different sectors of the Chinese economy. The sample period was 1992-2006. The results of their study showed that the activity of economic has had the greatest affirmative result on the variations in carbon emissions across all significant economic parts and the entire Chinese economy. The effect of CO_2 emission factor and structural changes were relatively small. Structural changes in agriculture only had an affirmative impact in the reduction of dioxide carbon emissions, also the effect of the CO_2 emission factor was effective only on the reduction of CO_2 emissions in the transport sector.

Martínez-Zarzoso and Maruotti (2011), in a paper titled 'The effect of Urbanization on Carbon Dioxide rises' studied the impact of urbanization on CO_2 emissions in a panel of developing nations between 1975 and 2003. They discovered the presence of an inverted U-shaped relation among pollution and urbanization. Their findings confirmed that the emission-urbanization relationship is positive for the low level of urbanization. This, they argued, is in line with the higher environmental impact noticeable in less developed environments.

Sharma (2011) explored the economic and social determinants of carbon emissions to a range of 69 developing and developed countries for the time of 1985-2005. The author tested the relationship by using energy consumption, GDP, urbanization rate and the degree of trade openness as explanatory variables within a dynamic econometric model. The research findings showed that there is an affirmative link among the trade openness degree, gross domestic product per capita production and energy consumption with carbon dioxide gas production. There is also an adverse link among the urbanization degree and CO_2 emissions in all countries with different income levels.

Table 1. Summary of other related studies

Author	**Period**	**Country/Region**	**Methodology**	**Variables**
Ang (2007)	1960–2000	France	ARDL, VECM Granger causality	CO_2, GDP, GDP^2, energy consumption
Azam and Khan (2016)	1975-2014	Tanzania, China, Guatemala, USA	OLS	CO_2, GDP, energy usage, trade openness, trade volume, urbanization growth rate
Baek (2015)	1960–2010	Arctic countries	ARDL	CO_2, energy consumption, GDP, GDP^2, GDP^3
Cho, Chu and Yang (2014)	1992–2004	132 developed and developing countries	OLS	CO_2, GDP, GDP^2
Dogan and Turkekul (2016)	1960-2010	United States	ARDL	CO_2, GDP, GDP^2,energy consumption, trade openness, urbanization, financial development

Gill, Viswanathan and Hassan (2017)	1970-2011	Malaysia	ARDL	CO_2, GDP, GDP^2, portion of renewable energy in total energy production
Iwata, Okada and Samreth (2010)	1960-2003	France	ARDL	CO_2PC, GDPPC, $GDPPC^2$, electricity production
Jalil and Mahmud (2009)	1975–2005	China	ARDL, Pair wise Granger causality	CO_2, GDP, GDP^2, energy consumption, trade openness
Kohler (2013)	1960–2009	South Africa	ARDL, Johansen cointegration, VECM Granger causality	CO_2, GDP, GDP^2, energy consumption, trade openness
Lau, Choong and Eng (2014)	1970–2008	Malaysia	ARDL, VECM Granger causality	CO_2, trade openness, GDP, GDP^2, FDI
Onafowora and Owoye (2014)	1970–2010	Brazil, China, Egypt, Japan, Mexico, Nigeria, South Korea, and South Africa	ARDL, VECM Granger causality	CO_2, energy consumption, trade openness, GDP, GDP^2, population
Pao and Tsai (2011a)	1980–2007	Brazil	Gray prediction model, Johansen cointegration, VECM Granger causality	CO_2,energy consumption, GDP, GDP^2,
Saboori and Sulaiman (2013b)	1971–2009	ASEAN	ARDL, VECM Granger causality	CO_2,energy consumption, GDP, GDP^2
Saboori, Sulaiman and Mohd (2012)	1980–2009	Malaysia	ARDL, Johansen cointegration, VECM Granger causality.	CO_2, energy consumption, GDP, GDP^2,
Shabhaz, Mutascu and Azim (2013)	1980–2010	Romania	ARDL	CO_2,energy consumption, GDP, GDP^2

Shahbaz, Lean and Shabbir (2012)	1971–2009	Pakistan	ARDL, Gregory–Hansen cointegration, VECM Granger causality	CO_2,energy consumption, trade openness, GDP, GDP^2,
Tan, Lean and Khan (2014)	1975–2011	Singapore	Johansen cointegration, VAR Granger causality	CO_2, GDP, GDP^2, energy consumption
Tang and Tan (2015)	1976–2009	Vietnam	Johansen cointegration, VECM Granger causality	CO_2, energy consumption, GDP, GDP^2, FDI
Tiwari, Shahbaz and Hye (2013)	1966–2011	India	ARDL, Johansen cointegration, VECM Granger causality	CO_2, trade openness GDP, GDP^2, coal consumption
Wang, Zhou, Zhou and Wang (2011)	1995–2007	China	Pedroni cointegration test, VECM Granger causality	CO_2,energy consumption, GDP, GDP^2,

Note: GMM = Generalized Method of Moments, OLS = Ordinary Least Squares, FMOLS = Fully Modified Ordinary Least Squares, VAR = Vector Auto Regression ARDL= Autoregressive Distributed Lag, FE= Fixed Effects, RE= Random Effects, DOLS = Dynamic Ordinary Least Squares, TSLS = Two Stage Least Squares VECM = Vector Error Correction model.

Chapter 4

DATA, MODEL SPECIFICATION AND METHODOLOGY

4.1 Data

The twelve countries that make up OPEC (Ecuador, Angola, Venezuela Algeria, Iran, Qatar, Libya, United Arab Emirate, Kuwait, Iraq, Nigeria, Saudi Arabia and Libya) are chosen as case study for this research. Annual data of all twelve countries, covering the years 1995-2014 was obtained for five variables created on the accessibility of data. In addition to carbon emission that serves as the dependent variable, other regressors included are; per-capita GDP, the per-capita square of GDP, fossil energy consumption, trade volume and urbanization. Data on all the variables was recovered from World Development Indicators (http://data.worldbank.org). Table 2 presents a summary of the variables, measurement of expected effects of the independent variables on the dependent variable.

Table 2. List of variables used

Variable	Measure	Notation	Expected Impact
Dependent Variable			
Carbon dioxide emissions	CO_2 emissions (metric tons per capita)	CO_2	
Independent Variables			
Gross domestic product	Per-capita GDP (constant 2010 dollars)	GDPPC	+
Squared gross domestic product	(per-capita GDP)^2	GDPPC^2	-

Fossil fuel energy consumption	Fossil fuel energy consumption (% of total)	FOSS	+
Trade volume	Exports + imports (% of GDP)		+
Urbanization	Urban population (% of total)	UR	+ -

Table 3 reports the summary statistics for carbon emissions, per-capita GDP, urbanization, trade volume and energy consumption. The result indicates that amongst the OPEC countries, Nigeria has the lowest mean carbon emissions (0.570599), while Qatar has the highest mean value (54.43937). In terms of the mean per-capita GDP values, Qatar is the richest (65858.58), whereas Nigeria is the poorest (1797.189). With regards to energy consumption, Qatar is the largest consumer on the average (18366.25), while Algeria is the smallest consumer (474.6066). Kuwait has the largest urban population ratio (99.57115), whereas Nigeria has the lowest urban population ratio (38.95785). At one extreme, United Arab Emirates is the most open in terms of international trade (133.6784), at the other extreme Venezuela is the least open of all the OPEC countries (50.10435).

Table 3. Summary statistics

Country	Minimum	Maximum	Mean
Panel A: Carbon emissions (metrics ton per-capita)			
Angola	0.471	1.330	0.922
Algeria	2.665	3.717	3.156
Ecuador	1.539	2.761	2.143
Iraq	2.189	4.884	3.674
Iran, Islamic Rep.	4.294	8.283	6.485
*Kuwait	25.223	34.036	29.268
*Libya	6.410	10.043	8.815
*Nigeria	0.325	0.770	0.570
*Qatar	37.780	70.135	54.439
*Saudi Arabia	10.445	19.52927	15.54308

*United Arab Emirates	15.424	35.67826	23.92592
*Venezuela	5.421	7.608296	6.378873
Panel	9.349	16.56501	12.94363
Panel B: GDP per-capita			
Angola	3223.558	4675.885	4005.741
Algeria	1476.231	3746.660	2560.704
Ecuador	3678.902	5428.714	4318.644
Iraq	4528.296	6622.673	5516.621
Iran, Islamic Rep.	2322.874	5390.010	4028.747
*Kuwait	35051.800	49588.760	40927.760
*Libya	4578.532	12120.560	9587.631
*Nigeria	1242.738	2563.092	1797.189
*Qatar	60460.420	72670.960	65858.580
*Saudi Arabia	16619.430	21183.460	19058.300
*United Arab Emirates	35037.890	64176.480	51727.720
*Venezuela	9710.307	14652.240	12778.460
Panel	14827.580	21901.620	18513.840
Panel C: Energy consumption			
Angola	798.144	1321.099	998.758
Algeria	429.832	552.6229	474.606
Ecuador	641.723	891.688	734.222
Iraq	1585.277	3023.490	2314.792
Iran, Islamic Rep.	893.829	1860.044	1218.678
*Kuwait	8566.780	11544.160	9956.954
*Libya	2209.890	3369.033	2959.611
*Nigeria	682.269	798.303	735.174
*Qatar	15233.920	21959.440	18366.250
*Saudi Arabia	4422.537	6937.231	5467.925
United Arab Emirates	7418.414	12087.100	9577.123
Venezuela	2047.273	2493.466	2210.870
Panel	3744.158	5569.806	4584.580
Panel D: Trade volume			
Angola	45.094	76.684	62.907
Algeria	90.261	152.547	119.859
Ecuador	43.395	68.056	54.382
Iraq	29.228	54.440	43.889
Iran, Islamic Rep.	0.020	154.234	91.778
*Kuwait	81.225	101.011	91.956
*Libya	34.801	138.897	83.811
*Nigeria	30.885	81.812	58.246
*Qatar	80.144	105.746	91.848
*Saudi Arabia	56.088	96.102	75.736
*United Arab Emirates	89.864	168.050	133.678
*Venezuela	38.520	60.127	50.104
Panel	51.627	104.809	79.849

Panel E: Urbanization			
Angola	55.997	70.221	63.320
Algeria	44.169	62.731	54.442
Ecuador	57.766	63.261	61.219
Iraq	60.236	72.830	66.963
Iran, Islamic Rep.	68.388	69.758	68.857
*Kuwait	98.096	100.000	99.571
*Libya	75.994	79.009	77.184
*Nigeria	32.205	46.982	38.957
*Qatar	94.998	98.868	97.219
*Saudi Arabia	78.670	82.960	80.848
*United Arab Emirates	78.319	85.375	81.950
*Venezuela	86.014	88.144	87.647
Panel	69.237	76.678	73.181

4.2 Model Specification

A modified version of the STIRPAT model is adopted in this study. Specifically, the affluence component (GDP per-capita) is included in a quadratic form to account for the possibility of non-monotonic relationships as put forward by the EKC hypothesis.

The econometric model is specified in order to test the augmented EKC hypothesis:

$$LCO2_{it} = \beta_0 + \beta_1 LGDPPC_{it} + \beta_2 LGDPPC_{it}^2 + \beta_3 LURban_{it} + \beta_4 LEC_{it} + \beta_5 LTRADE_{it} + \varepsilon_{it} \quad (6)$$

Where LCO_{2it}, $LGDPPC_{it}$, $LGDPPC_{it}^2$, $LURban_{it}$, LEC_{it} and $LTRADE_{it}$ are the logarithmic forms of CO_2 emissions, per capita gross domestic product, per capita squared gross domestic product, urbanization, consumption of fossil fuel energy per capita and trade volume respectively. So the main null hypothesis to be tested in this thesis is that, if there is a statistically significant relationship between the explanatory variables, listed above and dependent variable CO2 emission.

4.3 Methodology

4.3.1 Panel Unit Root tests

The panel unit root tests of Im, Pesaran and Shin (IPS) (2003), Levin-Lin-Chu (LLC) (2002), PP-Fisher Chi-square and ADF Fisher Chi-square tests are applied to test for the existence of panel stationarity. All these tests have a null hypothesis that there is a unit root against other different that variables. The Levin *et al*. (2002) is given as:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \sum_{j=1}^{p_i} p_i \Delta y_{it-j} + e_{it} \tag{7}$$

Where Δy_{it} is the difference of y_{it} for ith country in time period t = 1… T. This test is relied on the assumption of homogeneity such that $H_0: \beta = \beta_i \ = 0$.

The test of Im *et al*. (2003) introduces heterogeneity into equation (8) by allowing $\beta_i$vary across cross-sections i.e. under the different hypothesis, some but not all of the individual series may be non-stationary. The heterogeneous Fisher (1932) type panel tests of unit root suggested by Choi (2001), Maddala and Wu (1999), that perform the ADF and Phillips–Perron unit-root tests across cross-sections are the final panel unit root tests practical in this research. The test statistic is shown as:

$$P = -2 \sum_{i=1}^{N} ln\beta_i \tag{8}$$

4.3.2 Panel Cointegration Test

Cointegration tests of the combined individual tests of Johansen (Maddala and Wu, 1999), Pedroni (1999) and Kao (1999) are conducted to check the presence of long-run link between variables. The Kao test is a parametric, residual-based test and the null hypothesis is no cointegration. It is founded on LSDV regression equation given as:

$$y_{it} = \alpha_i + \beta X_{it} + e_{it} \tag{9}$$

Dickey Fuller/Augmented Dickey Fuller tests are offered to the residuals attained from the assessment of the regression equation. All the 5 variations of the Kao test assume that slope coefficient (β) are cross-section invariant.

Pedroni (1999)—also a residual-based cointegration examin that the null suggests there is no cointegration—relaxes the homogeneity assumption of Kao (1999). The underlying Pedroni (1999) regression equation is specified thus:

$$y_{it} = \alpha_i + \delta_i t + \beta_i X_{it} + e_{it} \qquad (10)$$

Where $\alpha_i, \delta_i \ and \ \beta_i$ are free to vary across cross-sections.

Two classes of statistics are considered by Pedroni (1999) based on the method of pooling residuals obtained from equation (5). The first class pools the obtained residuals on the within dimension (homogenous panel cointegration statistics), the second class on the other hand pools the obtained residuals along the between dimension (heterogeneous group mean statistics).

The final test, the combined individual test of Johansen as proposed by Maddala and Wu (1999), is a different cointegration method which applies the outcomes from the Fisher (1932) individual independent examinations to detect cointegration in panel data via joining examinations from individual cross-sections to generate a single test statistic for the whole panel. The statistic test is given as:

$$-2\sum_{i=1}^{N} ln\beta_i \rightarrow \chi^2 2N \qquad (11)$$

Where β_i is represents the p-value of the individual cointegration test for the ith cross-section.

4.3.3 Estimating the Cointegration Relationship with Weighted FMOLS

Fully modified ordinary least square estimators are well suited for estimating cointegrated panel regressions (Chen, McCoskey and Kao, 1999). FMOLS is a widely used panel estimation technique. It is a non-parametric approach that produces optimal cointegrating regression results (Phillips and Hansen, 1990). the technique makes adjustments for serial correlation and endogeneity due to presence of cointegrating relationships (Phillips, 1995).

This study employs the Kao and Chiang (2001) and Pedroni (2001) pooled FMOLS estimators for heterogenous panels that are cointegrated (weighted FMOLS). The approach allows changes in long-run variances across cross-sections.The corresponding estimator and asymptotic covariance are given respectively as:

$$\hat{\beta}_{fw} = \left[\sum_{i=1}^{N}\sum_{t=1}^{T} X_{it}^{*} X_{it}^{*,}\right]^{-1} \sum_{i=1}^{N}\sum_{t=1}^{T}\left(X_{it}^{*} y_{it}^{*} - \lambda_{12i}^{*,}\right) \quad (12)$$

$$\hat{V}_{fw} = \left[\frac{1}{N}\sum_{i=1}^{N}\left[\frac{1}{T^{2}}\sum_{t=1}^{T} X_{it}^{*} X_{it}^{*,}\right]\right]^{-1} \quad (13)$$

Chapter 5

RESULTS

To begin with, panel unit root tests of Im, Pesaran and Shin (IPS) (2003), Levin-Lin-Chu (LLC) (2002), PP-Fisher Chi-square and ADF Fisher Chi-square test were applied to assessment for the order of integration of the variables. This is a precondition for panel tests of cointegration. By these tests total of variables were verified with and without trend and in level and first differences. The test of the unit root outcomes are given in table 4.

With regards to carbon emissions, all the tests of unit root indicate that the variable is non-stationary at level under the no trend specification, and all the unit root tests except for the PP-Fisher chi-square indicate that the variable is non-stationary at level under the trend specification. After first differencing however, all the unit root tests, under both trend and no trend specifications show that the variable becomes stationary. Concerning GDP per-capita, all the unit root tests unanimously conclude that the variable is non-stationary at level under both trend and no-trend specifications. All the unit root tests again also unanimously agree that the variable is stationary after first differencing. With respect to urbanization, while the unit root tests suggest that the variable is stationary at level under the no-trend specification, when the trend specification is used, all the tests of unit root indicate which the variable is non-stationary at level. According to the tests of unit root, upon first differencing the variable becomes stationary irrespective of whether the trend or no-trend specification is used. All the unit root tests show that fossil fuel energy consumption is non-stationary at level under the no-trend specification, whereas all the tests asides PP-Fisher chi-square indicate that the non-stationary of variable at level under the trend specification. After first differencing, all the tests jointly agree that the variable becomes stationary. As for trade openness, whereas at level the variable is non-stationary irrespective of the trend specification, after first differencing the variable becomes stationary.

In summary, the unit root examination outcomes predominantly confirm the amount of unit roots at level and the lack of unit roots at first difference in all the variables. After confirming it strongly claimed that the variables are integrated of order one, I (1), cointegration examinations were next carried out to exactly there is long run relationship among the variables.

The Kao (1999) and Pedroni (1999, 2001) cointegration examination outcomes are stated in table 5. First, concerning the homogeneous cointegration examinations, evidence in support of the long-run relationship among the variables was recorded in 2 out of 4 of the Pedroni within dimension based tests (panel ADF statistic and panel pp- statistic) when both the trend and no-trend specifications were chosen. The Kao cointegration trial likewise shows the existence of cointegration between the variables.

With regards to the non-parametric, heterogeneous (between dimension based) cointegration tests (group-pp statistics), 2 out of 3 of them indicate that the variables are co-integrated in both the trend and no-trend specifications. Based on the more realistic group-pp statistics, this study concludes that the variables are cointegrated.

Table 4. Panel unit root tests

Variables		LLC		IPS		ADF–Fisher Chi-square		PP–Fisher Chi-square	
		No trend	Trend	No trend	Trend	No trend	Trend	No trend	Trend
Level	LCO_2	-0.864	1.471	-0.299	-0.543	29.402	27.131	50.267	51.437***
	LGDPPC	-1.890	-0.833	0.073	-0.578	30.122	23.973	17.659	18.417
	LUR	-16.185***	3.344	-12.887***	5.359	296.514***	13.968	501.173***	43.003
	LEC	0.718	2.804	2.381	2.210	12.176	6.864	28.064	52.376***
	LTRADE	4.347	24.213	0.959	0.086	10.721	13.940	44.935***	48.702
1st diff	ΔLCO_2	-12.489***	-9.455***	-13.188***	-9.187***	172.713***	120.510***	430.969***	177.995***
	ΔLGDPPC	-8.171***	-5.975***	-7.877***	-4.801***	103.211***	70.353***	148.915***	86.167***
	ΔLUR	-10.147***	-48.998***	-3.191***	-33.378***	69.088***	42.263**	82.856***	40.318**
	ΔLEC	-8.868***	-8.734***	-9.764***	-9.035***	131.662***	120.212***	264.527***	183.296***
	ΔLTRADE	-11.537***	-8.667***	-10.209***	7.006***	132.730***	89.030***	199.630***	148.234***

Table 5. Cointegration tests

	Within-dimension (homogenous)			**Between-dimension (heterogeneous)**	
No trend	Tests	Statistic	Weighted Statistic	Tests	Statistic
Pedroni	Panel v-Statistic	-1.245	-2.143	Group rho-Statistic	1.745
(1999, 2001)	Panel rho-Statistic	0.141	0.746	Group PP-Statistic	-5.106 ***
	Panel PP-Statistic	-3.537***	-3.739***	Group ADF-Statistic	-3.247***
	Panel ADF-Statistic	-3.037***	-3.315***		
Kao (1999)	ADF t-Statistic	-1.714**			

Trend	Tests	Statistic	Weighted Statistic	Tests	Statistic
Pedroni	Panel v-Statistic	-2.155	-3.324	Group rho-Statistic	2.306
(1999, 2001)	Panel rho-Statistic	1.470	1.724	Group PP-Statistic	-8.788***
	Panel PP-Statistic	-4.213***	-5.560***	Group ADF-Statistic	-5.119***
	Panel ADF-Statistic	-4.249***	-4.038***		

*Notes: (1) *, ** and *** mean statistic relationship significant at 10%, 5%, 1%, respectively; (2) automatic lag length based on Schwarz information criterion for lag selection is use*

Table 6. Johansen Fisher panel cointegration test

No. of CE(s)	**Trace statistic**	**P value**	**Max-Eigen value**	**P value**
None*	421.8	0.000	384.7	0.000
At most 1*	94.32	0.000	58.90	0.000
At most 2*	51.91	0.001	40.69	0.018
At most 3	29.69	0.195	29.69	0.195

The third cointegration examination employed is the Johansen Fisher Panel Cointegration test. Table 6 reports the outcomes from the tests. The reported associated probabilities for the trace test statistics refers at most 3 cointegration equations exist. This further provides evidence claimed that of there is stable long run relationship among the variables.

Finally, the long-run coefficients relationships were estimated via the FMOLS estimator. The regression outcomes are indicated in Table 6. The outcomes present the following. First, in line with the EKC hypothesis, GDP per-capita and the square of GDP per-capita have affirmative and negative coefficients respectively and both coefficients are significant statistically at one percent significance level. The founding indicate that a percentage rise in GDP per-capita will result in an increase of about 0.20 percent in carbon emissions, whereas a percentage increase in the square of per-capita GDP will cause a decline of about 0.15 percent in carbon emissions. This finding confirms the conclusions reached by authors like Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992), and Panayotou (1993).

Second, with regards to urban population growth, a coefficient of 0.99 suggests that for each percentage increase in urbanization, carbon emission is expected to increase by approximately 1 percent. This result is significant at 1 percent significance level. This finding lends some credence to the conclusions reached by McGranahan (2010) and Sadorsky (2014).

Third, a significant and positive long-run correlation is found among carbon emissions and energy consumption. When fossil fuel consumption rises in 1 percent, carbon emissions rise in 0.94 percent. This result is significant at 1 percent. This result is as the same works of Wang, Zhou, Zhou and Wang (2011), Shahbaz, Lean and Shabbir (2012), Shabhaz, Mutascu and Azim (2013), Tiwari, Shahbaz and Hye (2013), Tan, Lean and Khan (2014), and Tang and Tan (2015).

Fourth, the results show that international trade positively impacts carbon emissions. The results specifically show that when trade volume increases by one percent, carbon emissions will increase by approximately one percent. The result is significant at 1 percent. This finding strongly supports the position of Batra *et al.* (1998).

Finally, the overall goodness of fit of the regression represented via the R-squared and adjusted R-squared show that approximately seventy-five percent of the variation in carbon emissions is accounted for by joint variation in explanatory variables (per-capita GDP, urbanization, fossil fuel energy consumption and international trade volume). The remaining twenty-five percent is due to other factors not explicitly modelled in this study.

Table 7. FMOLS results

Regressors	**Coefficient**	**Standard Error**	**P-value**
LGDPPC	0.199***	0.032	0.000
$LGDPPC^2$	-0.147***	0.039	0.000
LUR	0.985***	0.002	0.000
LEC	0.944***	0.041	0.000
LTRADE	0.985***	0.049	0.000
R-squared	0.764		
Adjusted R-squared	0.745		
S.E. of Regression.	0.677		
Long-run variance	0.00096		

Notes: (1); Long-run covariance is estimated via the Bartlett kernel and the Newey-West fixed Bandwidth (2) Pooled (weighted) panel estimator for heterogeneous panels is used.

Chapter 6

CONCLUSION

This thesis examined the socio-economic determinants of carbon emissions within OPEC during the period 1995-2014 using panel estimation techniques. The test of unit root outcomes indicated which the variables are joined of fist difference. The Pedroni, Kao, Pe with Johansen Fisher panel tests cointegration confirmed which carbon emissions, GDP per-capita, urbanization, fossil fuel energy consumption and trade are cointegrated, an indication that a long-run link exists between all variables. The empirical outcomes obtained from the FMOLS regression offer support for a robust long-run link among carbon emission and socio-economic factors (GDP per-capita, consumption of fossil fuel, trade and urbanization) within OPEC nations. The key findings from this research indicate as follows;

The EKC theory holds within OPEC. The relationship between carbon emission and GDP is non-linear, and it is inverted U-shape suggested by the EKC theory. From the results GDP per capita has significant and positive effect on carbon emissions and GDP per- capita square has significant but negative impact on CO_2 emissions. An important suggestion of this finding is that the quality of environment is a normal good within OPEC countries, demand for it rises as income of member countries rise. This is mainly achieved through economies of scale, adoption of energy efficient technology, improved regulations and institutions to protect the environment and the emigration of dirty production process through trade openness.

The fact that urbanization is responsible for a significant proportion of carbon emissions in OPEC countries call into question the efficiency of urban planning policies within the organization. More attention to environmental issues is required when OPEC countries are making policies related to urban development, especially with regards to transportation management, land use and industrialization. In addition, greater degree of urbanization is linked with greater degree of economic activity. Furthermore, increased economic activity is associated with more wealth, and richer residents usually demand more energy-intensive items, most especially vehicles that run on fossil fuels. This leads to increases in carbon emissions.

Policies that focus on the achievement on efficient use of energy and adoption of energy renewable are therefore very important for sustainable environment in OPEC countries. Also, urban planners should prioritize optimum spatial matching between residential areas and location of urban amenities. This will prevent people from having to travel long distances to reach urban amenities, and cause a reduction in pollution caused by traffic congestions.

The fact that fossil fuel consumption is a significantly affirmative driver of carbon emission is not surprising since the volume of carbon emissions is obtained from the product of fuel carbon content and energy use intensity. It is thus expected that a strong positive correlation will exist between consumption of fossil fuel and carbon pollution. The effect of fossil fuel energy consumption on carbon emissions in OPEC countries is of a greater significance since energy costs are relatively lower as a result of heavy fuel subsidies. Such fuel subsidies result in relatively higher fossil fuel energy consumption which in turn leads to relatively higher CO_2 emissions in OPEC members.

A large quantity of CO_2 emissions within OPEC member countries is due to international trade. International trade through its role in environmental degradation is a source of international externality. The findings from this study show that the so called "race to the bottom" hypothesis should be of serious concern to OPEC member countries. According to the hypothesis, the more open countries are to international trade and investment, the more the likelihood that they will lower environmental standards. Simultaneously sustaining trans-border trade and limiting the resultant environmental impacts will require OPEC countries to enter into international agreements geared towards addressing the challenges posed by the trade-pollution nexus.

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The Impact of OPEC on Climate Change by David Rosnick 2018

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