Master's Thesis of City Planning

The Impact of Economic Growth on CO_2 Emissions and Energy Consumption

- In the Gulf Cooperation Council Countries -

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Abstract

The research aims to test the Environmental Kuznets Curve (EKC) hypothesis and analyses the causality relationship between carbon (CO_2) emissions, energy consumption, and Gross Domestic Product (GDP) per capita in the case of Gulf Cooperation Council - GCC - countries using the time series data for the period 1990-2014. Using the Vector Error Correction Model (VECM), it indicates that the EKC hypothesis does not hold in five of the six countries, and the inverted U-shaped curve was identified only in the UAE, regarding the direction of causality with Granger Causality and Vector Auto-Regressive (VAR) tests. It appears to be a unidirectional causality going from economic growth represented in GDP per capita to energy consumption. Such results suggest that reducing energy consumption and controlling CO_2 emissions policies could be adopted in the GCC economies without much concern about its effects on economic growth.

Keyword: GCC, Energy Consumption, Causality test, Environmental Kuznets Curve

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List of Abbreviations

ADF	Augmented Dickey-Fuller
ARDL	Autoregressive Distributed Lag
bcm	Billion Cubic Meters
BNEF	Bloomberg New Energy Finance
BP	British Petroleum
CH_4	Methane
CO_2	Carbon dioxide
CSD	Cross-Sectional Dependence
CSP	Concentrated Solar Power
DEWA	Dubai Electricity and Water Authority
EC	Energy Consumption
ECM	Error Correction Model
ED	Environmental Degradation
EG	Economic Growth
EIA	Energy Information Administration
EKC	Environmental Kuznets Curve
ELC	Electricity Consumption
FAB	First Abu Dhabi Bank
FMOLS	Fully Modified OLS

GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GDP2	Gross Domestic Product squared
GHG	Greenhouse Gas
GHI	Global Horizontal Irradiance
GM	Gray model
GWh	Gigawatt hours
HEI	Health Effects Institute
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
ISO	International Organization for Standardization
KPSS	Kwiatkowski–Phillips–Schmidt–Shin
KSA	Kingdom of Saudi Arabia
kt	kiloton
Mtoe	Million Tonne of Oil Equivalent
N_2O	Nitrous Oxide
NAFTA	North American Free Trade Agreement
OC	Oil Consumption
OLS	Ordinary Least Squares
OPEC	Organization of the Petroleum Exporting Countries
PP	Phillips-Perron
PV	Solar Photovoltaic

SDGs	United Nations Sustainable Development Goals
SO_2	Sulfur Dioxide
TPES	Total Primary Energy Supply
UAE	United Arab Emirates
VAR	Vector Auto-Regressive
VAT	Value Added Tax
VECM	Vector Error Correction Model

Chapter 1. Introduction

Energy is essential to humanity since it is a primary need for social and economic activities. The energy in all its forms is a prerequisite in the individual and national levels since it's a requirement for heating and cooling, lighting, and operating appliances. Also, it is used in almost every sector, such as water desalination, public transportation, production of nearly all goods and services. Therefore; providing access to energy services into affordable and modern way is a requirement for eliminating poverty and inequalities. Nevertheless, energy production and consumption are a significant source of air pollution that causes severe environmental issues and health problems all around the world, since it is ranked as the fourth-largest threat to human health globally according to the Health Effects Institute (HEI, 2018).

Outdoor air pollution is related to 2.9 million premature deaths globally annually (HEI, 2018). Furthermore; energy is the principal global source of greenhouse gas (GHG) emissions. According to the International Energy Agency (IEA, 2018), energy-related emissions have grown from 57% in 1990 to 70% of total GHG emissions in 2015. Additionally, in 2015 CO_2 was the largest source of energy-related GHG emissions, since the CO_2 shares reached around 90% of the of energy-related GHG emissions. Moreover, the CO_2 emissions from fuel combustion represented over two-thirds of the total GHG emissions. For these reasons, energy features prominently in the United Nations Sustainable Development Goals (SDGs), agreed by 193 nations in 2015 (IEA, 2018).

According to IEA (2018), between 2017 and 2040 world primary oil demand is expected to grow by 25%, as well as for gas by 55%, and 27% for coal as shown in Figure (1). This global demand is a result of the continued strong economic growth depending on fossil fuels, which leaves only a small amount of headroom for renewables to step in and meet incremental demand. Moreover, in the developing world the coal use will rise on the back of strong consumption to cover the increasing demand.

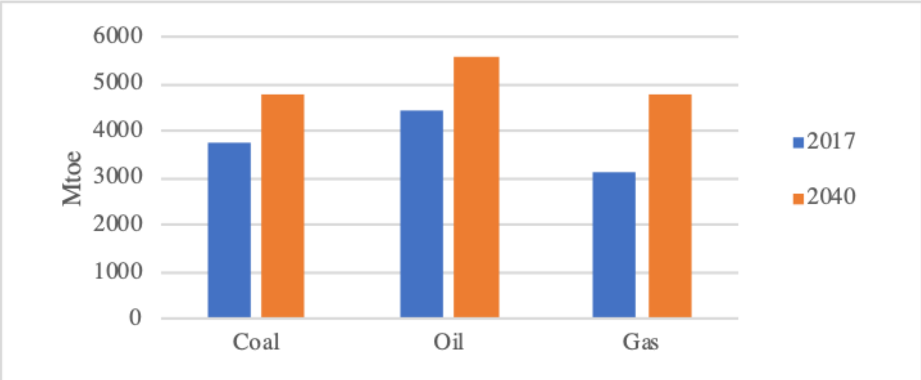
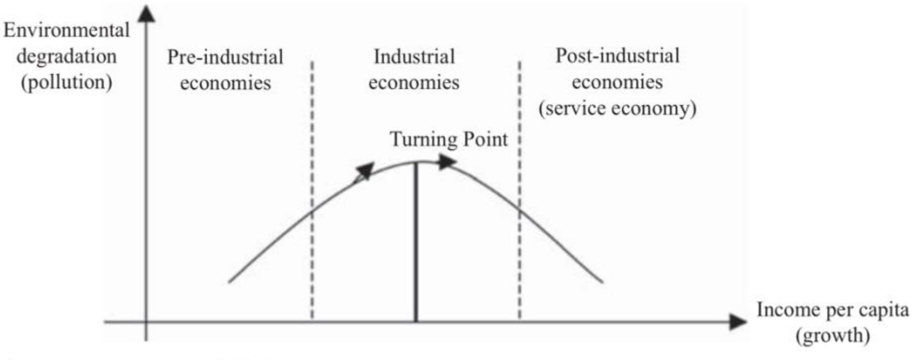


Figure 1 World primary oil demand (IEA,2018)

Apart from the future forecasting, the global energy-related CO_2 emissions have increased in 2017 after three years of remaining flat, which was generally driven by economic growth and a slowdown in the extent of energy efficiency policies. The active link between economic growth and environmental degradation has been widely discussed in the literature. The dilemma in this relationship is: Does the economic growth increase or decrease the environmental quality levels? The most common hypothesis related to this dilemma is with the economic growth, the environmental degradation increases too, due to ambient air pollution and several other factors. After environmental degradation reaches a turning point and start to slow down and environmental quality improves, the continuous increase in the income level.

This hypothesis is termed an "inverted U−shape," and it is also referred to as the Environmental Kuznets Curve (EKC) hypothesis in the literature, named after Simon Kuznets (1955). In the 1990s, this hypothesis was reinterpreted by researchers until Grossman and Krueger (1991) found a result similar to the Kuznets inverted U−shape relationship by studying the environmental impacts of a North American Free Trade Agreement (NAFTA). After this study, a massive number of researchers started testing EKC in many varied contexts and by using a different range of methodologies. Figure (2) shows the EKC hypothesis of the inverted U relationship that occurred because of the rise in income and emission levels. With further income increases, the emission levels reach a peak, or the turning point, and then start decreasing.



Source: Panayotou (1993)

Figure 2 Environmental Kuznets Curve (EKC)

Based on the results of testing the EKC in the literature, there were two cases involving either the absence or presence of the EKC hypothesis. The absence of the EKC hypothesis mostly occurs in developing countries since the economic growth in these countries did not reach the peak, or the turning point, where environmental degradation should decrease. The primary concern of these countries is achieving economic growth more than reducing environmental degradation. One primary reason behind this is that the income elasticity of environmental demand is low; therefore, the level of environmental awareness is also low (Shahbaz & Sinha, 2019).

In the case of the present EKC hypothesis, it mostly occurs in countries with developed economies. Since the economic growth in these countries is ecologically sustainable, reaching this stage could be done by restrictions to reduce fossil fuel-based energy consumption, or going for more renewable energy consumption. One primary reason behind this is that income elasticity of environmental quality demand in these countries is high, and the level of environmental awareness is also high. The social development is what differentiates these countries over others, which has a significant incentive for the improvement of environmental quality.

Apart from the EKC hypothesis, other relationships were the focus of many kinds of research, such as studying the relationship between energy consumption and economic growth. The recurrent dilemma in literature is that either economic growth requires more energy consumption or efficient energy consumption requires a high level of economic growth. After the Kraft and Kraft (1978) study, Granger causality approach has become a popular tool for studying the direction of the relationship between many variables in different countries. Several studies not only focused on the relationship between economic growth and energy consumption but also included environmental degradation. These studies aimed to study the direction of the relationship between the three variables by using different econometric methodologies instead of just the Granger causality test. This research will follow these studies' path, studying this relationship between the three variables by using one framework for the Gulf Cooperation Council (GCC) countries.

GCC was established by an agreement concluded on 25 May 1981 in Riyadh, Saudi Arabia. The GCC is a regional, intergovernmental, political, and economic union consisting of six Arab countries, Oman, Qatar, Kuwait, Bahrain, United Arab Emirates, and Saudi Arabia, all located in the Persian Gulf. The similar political and cultural identities which the GCC countries had it from the Arab and Islamic culture, where the purpose behind achieving the unity among the six countries. The six countries have one common language, Arabic, cover a total area of 2,673,108 km2, and their population is around 55,891,844, as estimated in 2018 (GCC 2018).

1.1. Purpose of Research

The essential objective of this paper is to explore the validity of EKC using time-series analysis for each country in the GCC over the period 1990–2014. This will be followed by studying the second objective, which aims to investigate the direction of the relationship between energy consumption, environmental degradation, and economic growth. Achieving these objectives will be by finding answers for the following research questions:

- Is the CO_2 emission per capita and GDP per capita supporting the EKC hypothesis for the GCC countries?
- Is there a causal relationship between energy consumption, CO_2 emissions and economic growth in GCC Countries? If there is a causal relationship. What is the direction of it?

Answering these questions will be done by employing the recently developed panel data methods, such as panel unit root tests and Vector Error Correction Model (VECM) test. From this perspective, this study will add value to the existing literature related to GCC countries by adding a recommendation in to the sustainable environmental policy research, which may also be a basis for the GCC countries.

This research aims to assist the GCC countries in improving their positions concerning environmental pollution. The GCC countries are prosperous with hydrocarbon resources; they had 29% of the global oil reserves and 22% of the global natural gas reserves according to the International Renewable Energy Agency (IRENA,2019). The GCC countries' economies are highly dependent on the export of oil and gas products. On the other hand, the GCC countries had a considerable share from the Arab world's CO_2 emissions, since it contributes 50% of the total Arabic emissions (Tolba and Saab, 2009). For the global contribution, the GCC countries had approximately 8% of the global CO_2 emissions (Ozturk, I., & Salahuddin, M., Gow, J., 2015).

1.2. Structure of Research

The rest of this paper is structured as follows. The Current Status of GCC Countries chapter contains a full description of the rapid economic growth of the GCC, and how it is related to high energy consumption and CO_2 emissions. Next will be the Literature Review chapter, which contains a review of the literature on the EKC hypothesis, the causality relationship between GDP per capita, CO_2 emissions per capita, and energy consumption per capita, and literature related to the GCC countries.

Then there is the Data Source and Model chapter. After it, the econometric techniques used in the paper are outlined in the Empirical Techniques chapter. The tests' results are presented in the Empirical Findings and Analysis Results chapter. The policies that would be recommended based on the empirical results will be under Policy Implications. The last chapter contains the concluding remarks.

Chapter 2. Current Status of GCC Countries

2.1. Economic Growth

The GCC countries' economy is one of the rapidest growing economies in the world. The GCC economic flourish came after the oil and natural gas boom, as it is shown in their growing GDP for the last decades. The total GDP for the six countries was around $3.515 trillion in 2017, and the GDP per capita was $69,906 (World Bank 2018). The GCC included two of the largest economies, Saudi Arabia and the UAE, which together accounted for about two-thirds of the regional gross domestic product (GDP) in 2018 (FAB[①] 2018a).More fully, Saudi Arabia is holding 47% of the region's GDP, UAE came second with 26%, and then Qatar and Kuwait at about 11% and 9%, respectively (FAB 2018a). The GCC had a high increase in the annual growth rate of GDP from 1990 to 2016, since it increased by 7% for Saudi Arabia, Kuwait, and Oman, by 8% for the UAE and Bahrain, and lastly by 12% for Qatar (IEA, 2018b). This rapid economic growth depends mostly on the hydrocarbon resources, since the oil and gas sectors are the major contributors to the GCC's GDP.

① First Abu Dhabi Bank (FAB)

The GCC countries are the world's most important oil-producing region since they are holding about 29% of the global oil reserves. Besides the oil, they hold 22% of the global natural gas reserves. Most of the GCC countries' oil production used to be exported, on account of the high reserves compared to the small domestic consumption. Despite the region's domestic energy demand rising extremely over the past decades, the GCC is still able to supply crude oil to the international market by 28% of the total shares. This is approximately under a third of the crude oil supplied to the international market and estimated to be more than two-thirds of the Middle East region's exports of crude oil (IEA, 2018).

On the other hand, natural gas plays a much smaller role in international markets than oil, accounting for only 13% of global exports in 2017 (OPEC[2], 2018) despite the fact that Saudi Arabia holds the world's sixth-largest natural gas reserves, which is the second-largest in the region after Qatar. Qatar is estimated to hold about 24.9 billion cubic meters (bcm), which makes it the world's third largest holder of reserves after the Russian Federation and Iran (IEA, 2018). As a result, the economy of these countries is highly dependent on the production of fossil fuel products. Furthermore, the six countries were listed in the world's ten-largest crude oil producers in 2017; however, only Qatar and Saudi Arabia were listed on the world's ten-largest natural gas producers for the same year (BP[3], 2018). Succinctly, oil and gas reserves, production, and exports are the source of GCC's high GDP and per capita GDP.

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[2] Organization of the Petroleum Exporting Countries
[3] British Petroleum

2.2. Energy Consumption

The domestic energy demand has risen over the last decades in the Middle East; according to IEA (2018), the total energy demand will increase by 48% in the region in 2040. While 87% of the increment will come from oil and gas resources, 1% will come from coal, and the remaining 12% will come from renewables as shown in Figure (3) (IEA, 2018).

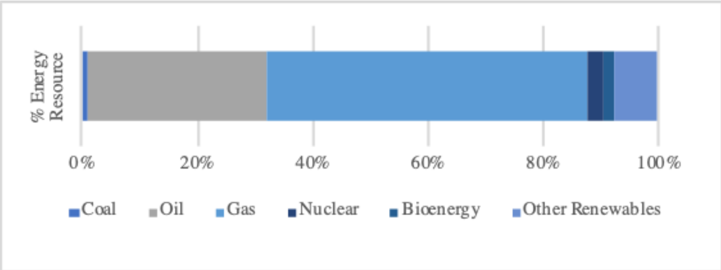


Figure 3 Middle East energy demand

The total primary energy supply (TPES), which is the sum of production and imports subtracting exports and storage changes, for the GCC countries is 401.21 Million Tonnes of Oil Equivalent (Mtoe) in 2016 (IEA, 2018). The domestic energy for the GCC depends on the fossil fuels. Figure (4) shows sharp growth of the energy primary supply by oil and gas and the shortage of energy primary supply by renewables. Therefore, we found oil is holding 42.7% of the TPES and natural gas holding 56.8%, which totals around 99% of the TPES. On the other hand, the renewables had the lowest share after the coal by 0.03%, and coal is holding 0.25% of the TPES (IEA, 2018).

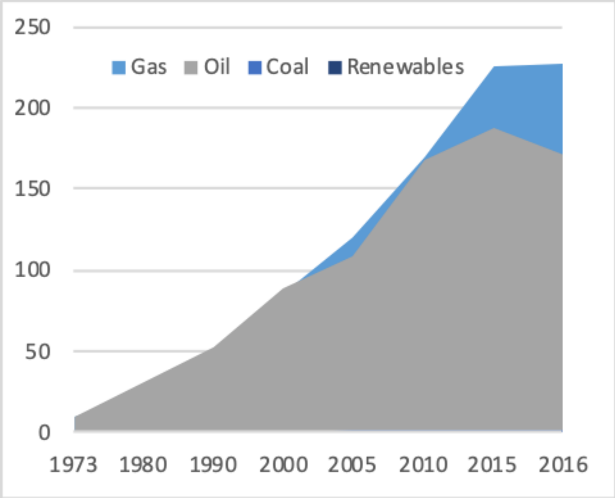


Figure 4 The TPES of GCC countries

The GCC countries were listed between the top ten highest energy consumption per capita in the world in 2014, with Qatar as the highest by 18562.7 kg of oil equivalent per capita (World Bank 2019). Despite that, the total final consumption of energy has decreased by 3% from 2015 to 2016 in the GCC countries. The total final consumption of energy in GCC countries increased dramatically in the 1973–2015 period. The majority of the consumption goes for Saudi Arabia and the UAE, which in total take around 73% of the consumption shares, 55% for Saudi Arabia and 21% for the UAE (IEA, 2018).

2.3. CO_2 Emissions

The GCC countries were listed among the top ten highest CO_2 emissions per capita in the world in 2014, with Qatar as the highest by 45.5 tonnes (World Bank 2019). Despite the fact that the 2016 CO_2 emission per capita in the GCC countries decreased by more than 2% from 2015 to 2016, the CO_2 emission per capita for

GCC countries has had an overall increasing trend in the period from 1971 to 2015 (IEA, 2018).

The GCC countries depend entirely on fuel for their energy production; therefore, CO_2 emissions from fuel combustion have rapidly increased from 34.6 million tonnes in 1971 to 9,816 million tonnes in 2016. The majority of the consumption is in Saudi Arabia and the UAE, with more than 70% of the emissions shares, 54% holding by Saudi Arabia and 20% for the UAE (IEA, 2018). Figure (5) shows the CO_2 emissions from fuel combustion growth from oil and gas in total for the six of the GCC countries. Therefore, we found oil is holding 50% of the emissions and natural gas holding 49%, which, in total, is around 99% of the CO_2 emissions from fuel combustion.

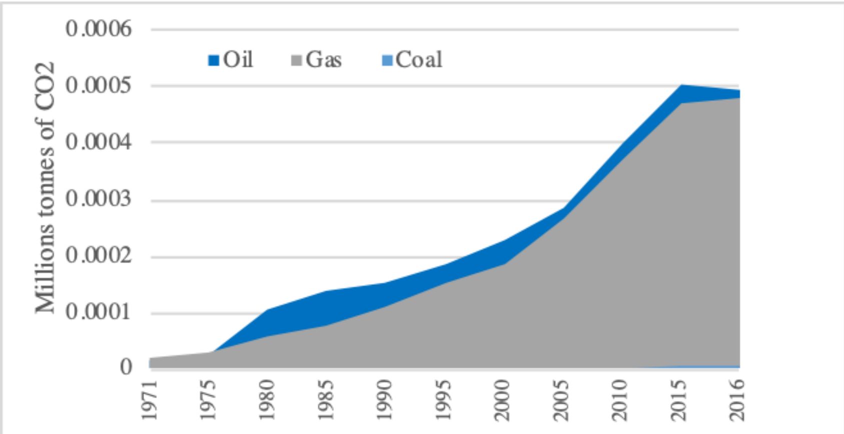


Figure 5 CO_2 emissions from fuel combustion

At the sectoral level, emissions from each sector differ among the six countries, but the highest share is allocated to electricity production, which is 44% of the total CO_2 emissions from fuel combustion across other sectors. On the other hand, the transport sector accounted for the third-largest share of the total CO_2 emissions from fuel combustion after manufacturing and construction. The transport sector accounts for 22% of the shares and manufacturing and the construction sector account for 24% of the total CO_2 emissions from fuel combustion, as shown in Figure (6) (IEA, 2018).

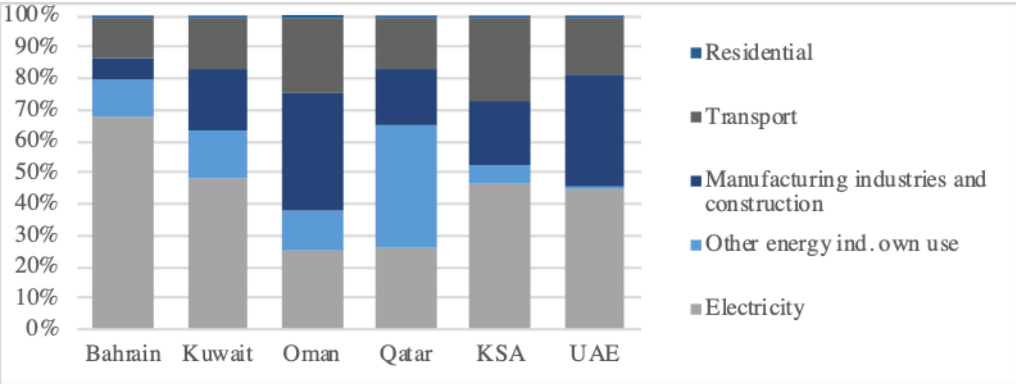


Figure 6 Total CO_2 emissions fuel combustion by sector 2016

From the previous facts related to the economic growth, energy consumption, and CO_2 emission of the GCC countries, we may conclude that these countries are facing a difficult situation as their energy production depends mainly on fossil fuels. On the other hand, the GCC economy is based on the oil, gas, and petrochemical industries, which are the leading causes of CO_2 emissions. Even though the GCC accounts for only 3% of the total carbon emissions all over the world, their per capita emissions are very high compared to other regions (World Bank 2019).

The GCC countries are playing an increasingly important role in climate change; since they are the world's main petroleum producers and exporters as well as victims of climate change. If sea levels rise as a result of the climate change, natural and human-made islands in the region will disappear, with Bahrain potentially losing up to 15 kilometers of coastline. Furthermore, underground water salinity and land degradation will increase, and the biodiversity on land will be affected (Mohamed A. 2008).

It is thus clear that the GCC countries must work on sustainable environmental policies to improve their position related to environmental pollution, since they share responsibility with the rest of the world for climate change. This research aims to assist in developing a sustainable environmental policy by studying the relationship between EG, EC, and CO_2 emissions in the GCC countries.

Chapter 3. Literature Review

There is an enormous amount of available literature studying the relationship between CO_2 emission, EC, and EG. This literature can be divided into three different categories based on the variables in the relationship. The first category focuses on studying the relationship between economic growth and environmental degradation, which represents the EKC hypothesis. The second category studies the relationship between economic growth and energy consumption. The third category, on the other hand, studies the three variables in one framework. Details on each category are presented below.

3.1 Studies related to the EKC hypothesis

Simon Kuznets (1955) was the first who formulated the concept of the inverted U-shaped relationship between EG and ED. Grossman and Krueger (1991) wrote the first empirical paper concerning the EKC hypothesis since they found a similarity with Kuznets' inverted U-curve concept while studying the relationship between economic growth and environmental degradation. After the finding of Grossman and Krueger (1991), a massive number of studies started to focus on the existence of the EKC hypothesis by using a great range of methodologies. These studies used various air pollution indicators, such as CO_2 emissions, SO_2 emissions, methane (CH_4) emissions, and nitrous oxide (N_2O), as well as different water and soil pollutions.

The empirical results that have been obtained from the studies primarily differed concerning the different choice of variables and different model qualifications. As a result of those differences, the shapes of EKC and its turnaround points were different from a study of others. With time, several variables, such as energy consumption, trade, political collaboration, and mortality rate, have been considered within the EKC framework. Consequently, the results for the same country or any group of countries were different; some scholars have found evidence to support the existence of the EKC hypothesis, while on the other side, scholars did not find any evidence for it.

Some scholars, such as Fodha, M. & Zaghdoud, O. (2010), have used more than one air pollution indicator in one farm's work. This research aims to examine the relationship between economic growth and environmental degradation in Tunisia during the period 1961–2004 by using the EKC hypothesis. However, this paper has used carbon dioxide (CO_2) and sulfur dioxide (SO_2) as environmental degradation indicators, and per capita GDP as an economic growth indicator. The results indicate that there is a monotonically increasing linear relationship between per capita CO_2 emissions and per capita GDP. On the other hand, the relationship between SO_2 and per capita GDP is shown as an inverse U-shape, which represents the EKC hypothesis and depicts that the result of the EKC could be made different by using different pollutant emissions.

He, J., & Richard, P. (2010) is the first single-country EKC analysis that studied CO_2 emissions with consideration for fossil fuel energy consumption. The paper studied Canada throughout 1948–2002, by using the OLS approach. The study found that the EKC for Canada has an inverted U-shape with the turnaround point at $22,615. Moreover, the researcher found there was a direct positive impact from the fossil fuel-based energy consumption to the CO_2 emissions. Notwithstanding, other studies have found an N-shaped EKC as a result of studying CO_2 emissions, such as Akbostancı et al. (2009). This study had used the cointegration test throughout 1968–2003 for Turkey. It was the first study to use the cointegration technique to examine the EKC for CO_2 emissions, which led to getting the inverted N- shaped form as a result of the EKC, with two turnaround points at $1,437.80 and $1,603.90 respectively.

On the other hand, some studies had included other elements in the EKC equation, such as energy consumption, trade, or financial development. Jalil and Feridun (2011) added financial development data for the over 1953-2006 for studying EKC validity in China. By using VECM and Granger causality, they found that financial development can enhance environmental quality.

Several studies, such as Ang, J.B. (2007), have found evidence of an inverted U-shaped EKC relationship, by using the ARDL bounds test and VECM for France between 1960 and 2000. Other studies, for example, Pao, H., & Tsai, C. (2011), have found the effects of the EC on environmental degradation and the presence of an inverted U-shape by using the Gray model (GM) and VECM for Brazil from 1980 through 2007. Nevertheless, other studies have failed to find evidence of an inverted U-shape, such as

Artaxo, P. (1998), who studied 23 countries from 1974 to 1989 by using panel cointegration analysis. From the literature, we can see that there are divergent ideas regarding the shape and turnaround point of EKC across the geographical context and the econometrics methods. Appendix (I), represent a summary of the studies examining the validity of EKC hypothesis.

3.2. Studies related to energy consumption and economic growth

The causality between energy consumption and economic growth was the focus of a massive part of the literature. This relationship has been structured around four hypotheses: the growth, the conservation, the feedback, and the neutrality hypotheses. First, the growth hypothesis involves a unidirectional causality running from energy consumption to economic growth. This hypothesis claims that energy consumption has a dominant role in economic growth. Therefore, in this case, energy conservation policies for reducing energy consumption will have a negative impact on economic growth.

The second hypothesis is the conservation hypothesis, which claims a unidirectional causal relationship running from economic growth to energy consumption. In this instance, since energy consumption is a limiting factor to economic growth, energy conservation policies will not have an unfavorable effect on economic growth. Third, the feedback hypothesis implies a bidirectional causality between energy consumption and economic growth. According to the feedback hypothesis, energy conservation policies will reduce economic growth, and similarly, any change in economic growth will affect energy consumption. Finally, the neutrality hypothesis represents the absence of causality between energy consumption and economic growth. With these results, the energy conservation policies that aim to reduce energy consumption will not have any impact on economic growth.

The literature related to energy consumption and economic growth can be classified into studies that focus on studying only a single country versus others that extend to more than one country. Moreover, some of the studies were examining electricity consumption, while others were including total energy consumption. A list of the literature on the causality between energy consumption and economic growth ordered by author(s), publication year, country, data period, empirical methodology, and empirical results is in an Appendix (I).

3.2.1. Single country studies on economic growth- energy consumption nexus

The causality relationship between energy consumption and economic growth was introduced in the seminal paper by Kraft and Kraft (1978), who examined this relationship for the United States. Using Granger causality methodology and data on energy consumption and economic growth for the United States from 1947 to 1974, Kraft and Kraft found that there was a unidirectional causality relationship going from GNP to energy consumption. Since then, more literature has examined the relationship between energy consumption and economic growth, such as Abosedra and Baghestani (1989) who used cointegration and Granger causality methodology. For this paper, the authors have used the data over the period 1947 to 1987 for the United States, and found that there is a unidirectional causality relationship going from economic growth to energy consumption. Cheng (1999) also found that a unidirectional causality relationship was running from economic growth to energy consumption during studying India. That paper used data from 1952 to 1995 and depends on the Cointegration models and Granger causality as a methodology.

On the other hand, Stern (1993) and (2000) has found unidirectional causality relationship, but it ran from energy consumption to economic growth for both of his papers. Stern used different methodologies in his studies for the same period, which was the post-war period after 1948 in the United States. For the first paper, Stern used Granger causality in a multivariate setting using a vector autoregression VAR. model of GDP, energy use, capital, and labor inputs. The second paper used cointegration analysis with Granger causality. Likewise, Oh and Lee (2004) had found a unidirectional causality relationship going from energy consumption to economic growth when they examined the casual relationship for South Korea. They used a Granger causality with cointegration model among the variables, throughout 1970–1999.

Other researchers, such as Ghali and El-Sakka (2004), found that there was a bidirectional causality between energy consumption and economic growth. Their study focused on Canada over the 1961–1997 period by using the Granger causality and a VEC model after testing for multivariate cointegration. Similarly, Paul and Bhattacharya (2004) found there was a bidirectional causality between energy consumption and economic growth by applying the Engle-Granger approach with the standard Granger causality process in India for the period 1950–1996.

Overall, several empirical studies on the relationship between economic growth and energy consumption for a single country had inconclusive and mixed results. "The absence of consensus can be explained by the difference in periods, used variables, model specifications, and econometric methodologies undertaken" (Tiba, Omri,2017).

3.2.2. Multi-country studies on economic growth–energy consumption nexus

There is much literature covering multiple countries in the examination of the causal relationship between energy consumption and economic growth, using different methodologies and having obtained different results. For example, Asafu-Adjaye (2000) has studied four Asian countries, India, Indonesia, the Philippines, and Thailand, using cointegration and the Granger causality based on ECM modeling techniques. In the short run, the study found there was unidirectional causality running from energy consumption to income in India and Indonesia, whereas in Thailand and the Philippines, there existed a bidirectional causality.

Soytas and Sari (2003) studied sixteen countries among the top emerging markets and the G-7 countries by using annual data between 1950 and 1992, the cointegration model, and the Granger causality test. They found there was a stationary linear cointegrating relationship between the variables for only seven out of the sixteen countries. The result for these seven countries was: Argentina had a bidirectional causality from energy consumption to economic growth and back; Italy and Korea had a unidirectional causality running from economic growth to energy consumption; and

Turkey, France, Japan, and Germany had a unidirectional causality running from energy consumption to economic growth.

The last paper, by Mishra et al. (2009b), studied the Pacific Island countries, examining annual data from 1980 to 2005 to find the causality relationship between energy consumption, GDP and urbanization. Moreover, the focus was on nine Pacific Island countries: Fiji, French Polynesia, Kiribati, New Caledonia, Papua New Guinea, Samoa, Solomon Islands, Tonga, and Vanuatu. The authors relied on the Granger causality to test the three variables, and the long-run of the test found there was a bidirectional Granger causality between energy consumption and GDP for the nine countries. The test showed that an increment by 1% in energy consumption increases GDP by 0.11%, while a 1% increase in GDP increases energy consumption by 0.23%. The author had two reasons behind these results: “First, economic growth results in an expansion in the commercial and industrial sectors, which requires energy inputs. Second, higher disposable income increases demand for electronic gadgets for entertainment and comfort for households.”

Overall, the results from the literature covering multi-country surveys are conflicting, and there is no consensus on the existence or the direction of causality between general energy consumption and economic growth. Even in one study that examines the relationships in countries within the same continent that are near to each other and have the same culture and weather, there were differences in the direction of the causality relationship between energy consumption and economic growth. For example, Wolde-Rufael (2005) tested nineteen African countries, which were categorized into the four categories of the causality relationship; also, Asafu-Adjaye (2000) studied four Asian countries, which were categorized into two categories of the causality relationship.

3.3. Studies related to the three variables

The third research area was focusing on the relationship between the three variables of energy consumption, environmental degradation, and economic growth. Those studies are combining the testing of the present EKC hypothesis and the causality relationship between energy consumption and economic growth. Appendix (I) summarizes the literature that covered this area, showing the authors names, results, data periods, and methodology for each study. Starting with Ang (2007) which investigated the relationship between the three variables by using the cointegration and VECM for France through 1960-2000. The results from this paper showed evidence supporting the existence of EKC for CO_2 emissions in France. On the other hand, the causal relationship runs from energy consumption to economic growth.

Alam et al. (2011) investigated the causality relationships among energy consumption, CO_2 emissions, and income in India covering the period from 1971 to 2006. By using a dynamic modelling approach, their findings for the long-run support the existence of a bi-directional Granger causality between energy consumption and CO_2 emissions. Nevertheless, there was no causality going from the CO_2 emissions or energy consumption causes economic growth. In other words, there was no evidence for the existence of EKC in the long-run for India.

Ozturk and Acaravci's 2013 paper aimed to examine the causal relationship between financial development, trade, economic growth, energy consumption, and CO_2 emissions in Turkey for the 1960–2007 period. The results support the validity of the EKC hypothesis in the Turkish economy by using the F-test for cointegration test. Moreover, there was evidence of a short−run unidirectional causal relationship running from financial development to per capita energy consumption and per capita real income.

On the other hand, there was literature studying the relationship between the three variables for more than a single country, such as that of Burcu Ozcan (2013). This paper studied twelve Middle East countries during the period 1990–2008 by employing FMOLS and ARDL models. The results from this paper supported the existence of KEC in only five out of the 12 countries. Regarding the direction of the causality relationship, there was unidirectional relation running from economic growth to energy consumption in the short run. For the long run on the other side, there was a unidirectional relation running from energy consumption and economic growth to CO_2 emissions.

3.4. Studies related to the GCC countries case

There are limited numbers of studies that focus on studying energy consumption, CO_2 emissions, and economic growth for the GCC countries. Most of the literature related to these countries either study the EKC alone or the causality relation alone, with a rare number of studies combining both in one framework. Alsamara, Mrabet, Saleh, & Anwar (2018) combined both testing the EKC and causality relation by using panel data over the 1980–2017 period for two indicators of environmental pollution: CO_2 and SO_2 emission. The authors found that EKC does not hold for Oman, Bahrain, and

Kuwait and that there exists a one-way causality from real GDP per capita to CO_2 emissions and from real GDP per capita to SO_2 emissions.

Al-Iriani's (2006) study focused on the causal relationship between GDP and energy consumption for the annual data of 1970–2002. By applying the panel cointegration test, the results showed a unidirectional causal relationship running from GDP to energy consumption for the six countries, even though they had different GDP per capita and economic focus; on the other hand, they had almost the same culture and climate, which can control consumer behavior.

Basarir and Arman (2013) focused on the EKC in the GCC during 1980–2010 and showed that EKC holds in Bahrain, KSA, and UAE. Nevertheless, the EKC has a U-shaped curve for Kuwait and Qatar. Oman, on the other hand, did not exhibit any significant relationship between environmental pollution and income per capita. The study by Bader and Ganguli (2019) included health indicators in the picture as well. The paper used the data for pollution indicators CH_4 and CO_2, health indicators, GDP per capita, and economic time-series for GCC countries during 1980–2012. The paper found evidence of a U-shaped relationship between environmental pollutants and GDP per capita in Bahrain and Saudi Arabia. UAE, on the other hand, confirms EKC, though not significantly. On the other side, the growing incomes have a crucial role in improving the health standards by reimbursing some of the negative effects from lack of environmental improvement, since there is an absence of EKC in general in GCC. A summary of the relevant studies is reported in an Appendix (I).

Overall, we can see some of the literature was neither focusing on the EKC alone, nor able to investigate both the EKC and the causality relation. Some researchers were able to find a valid EKC hypothesis, and some could not get such results. This research will combine the two approaches by investigating the causality relationship between the three variables and testing the existing of the EKC for GCC countries.

Chapter 4. Data Sources and Model

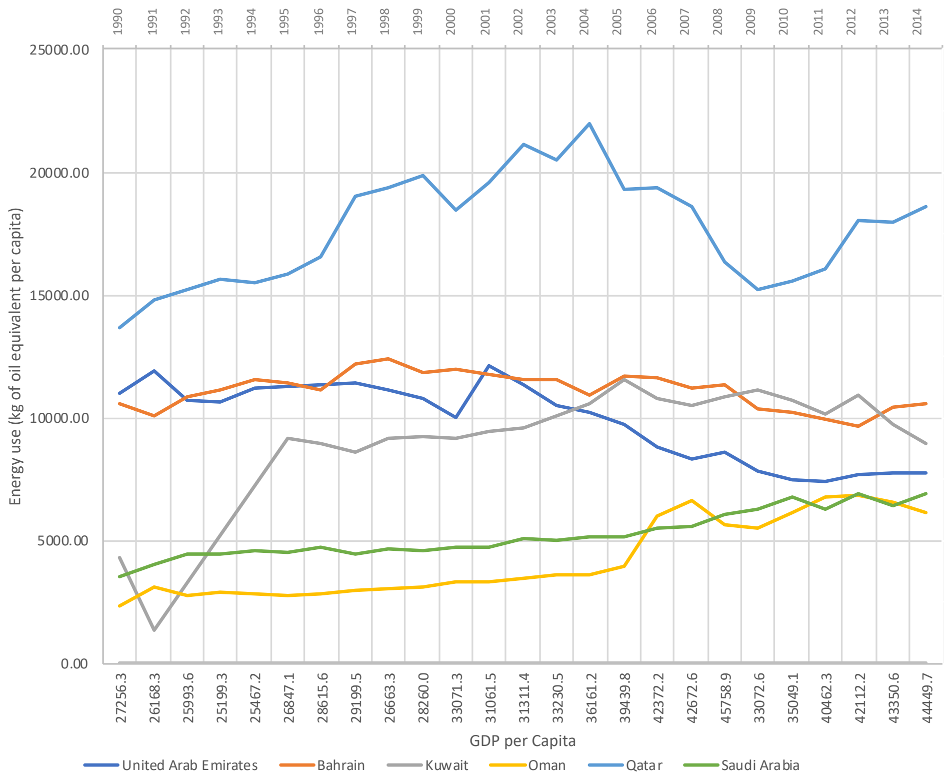
4.1. Data Sources

Using the World Bank Development Indicators database (WDI 2018) for six GCC countries during the period from 1990 to 2014 presented in Appendix (III), the selection of this time period was dictated by data availability. This research will use the GDP per capita, as a proxy for the economic growth of each country. The second variable will be the energy consumption per capita, which measured by kt (kiloton) of oil equivalent. Moreover, the third variable will be the CO_2 emissions, was taken as the proxy of environmental degradation and calculated as metric tons per capita. Choosing the CO_2 as the environmental degradation indicator based on "anthropogenic carbon dioxide emissions through the combustion of fossil fuels appear to be the major contributor of global warming" (Ghosh, 2010).

Furthermore, CO_2 is holding about 58.8% of the GHG over the other environmental pollutants that causing climate change (Burcu Ozcan 2013). Nevertheless, there are many studies using other environmental degradation indicators such as nitrogen oxide, sulfur emissions, suspended particulate matter, and water pollution such as Grossman and Krueger(1995) ; Perman and Stern(2003); Rothman (1998); Stern (2005); Zaim and Taskin (2000).

Visual inspection has been made by using the available data of the GDP per capita, CO2 emissions, and energy consumption per capita, to identify the relationship between the three variables as initial investigation. It found that there was a positive relationship between energy consumption per capita and GDP per capita that appears in Figure (7).

Figure 7 Relationship between EC and GDP per capita in the GCC



In the same way, Figure (8) shows the positive relationship between energy consumption per capita and CO_2 emissions per capita, which was expected as the GCC countries depend on the fossil fuel in their energy production. Moreover, the graphical analysis relationship between GDP per capita and CO_2 emissions represent in Figure (9) which can be considered as initial anticipation for the validity of EKC hypothesis, and it does not support the inverted U shaped of the Kuznets curve. The empirical results in this research support these visual inspections as well, which will be in details in the empirical findings section.

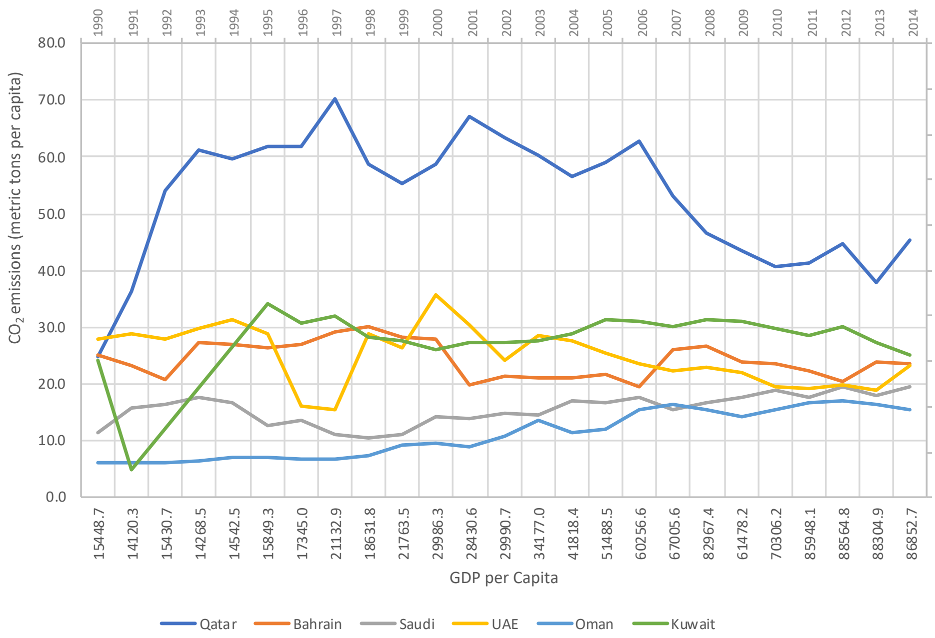


Figure 8 Relationship between GDP per capita and CO_2 per capita

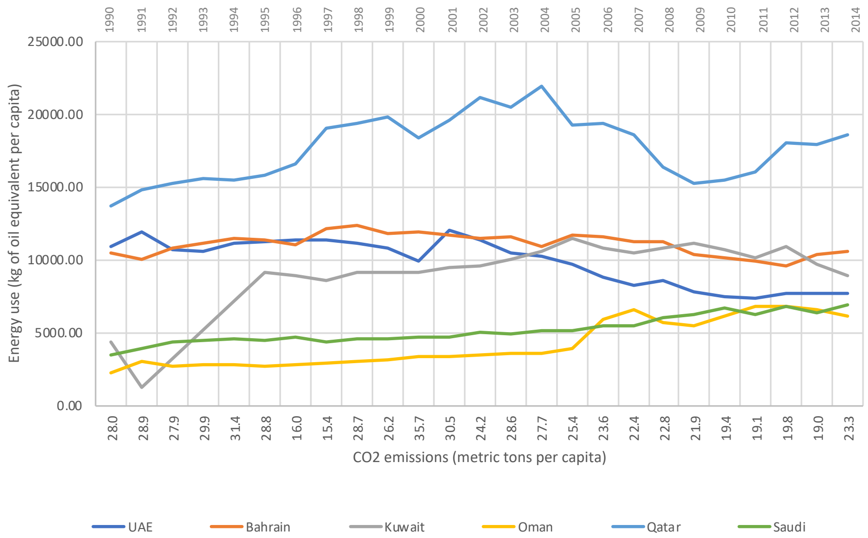


Figure 9 Relationship between CO_2 per capita and EC per capita

Table (1) presents the summary statistics related to GDP per capita, CO_2 emissions per capita, and energy consumption per capita for the six countries and panel set over the period 1990–2014. The mean energy consumption per capita ranges from (735.65) in Bahrain as the least usage to (3135.08) in Kuwait as the highest usage. Moreover, for the mean of CO_2 per capita, Qatar is the highest emitter with (11.18 kt) and KSA the least emitter with (2.68 kt) metric tons per capita emission. Regarding GDP per capita, Qatar is the wealthiest country (28183.72$), while Bahrain is the poorest one (5707.70$). Furthermore, Oman has the least variation (i.e. the least standard deviation) in CO_2 emissions per capita (11.15 kt), energy consumption per capita (4245.35) and per capita GDP (11783.85$). While, Qatar has the highest variation in CO_2 emissions per capita (52.99 kt) and GDP per capita (43044.37$), in per capita energy consumption (17688.34).

Table 1 Statistics summary for the GCC countries (1990-2014)

Countries	S.D.	Mean	Minimum	Maximum
Panel A: CO_2 emission per capita (kt per captia)				
UAE	5.09	24.98	15.42	35.68
Qatar	11.18	52.99	24.70	70.10
Bahrain	3.10	24.30	19.65	29.99
KSA	2.68	15.56	10.40	19.50
Oman	4.10	11.15	6.10	17.10
Kuwait	7.45	26.05	5.01	34.04
Panel B: Energy consumption (kt of oil equivalent per capita)				
UAE	1584.30	9879.97	7418.41	12087.10
Qatar	2216.34	17688.34	13698.29	21959.44
Bahrain	735.65	11114.20	9657.57	12406.71
KSA	940.23	5216.04	3552.71	6937.23
Oman	1597.37	4245.35	2328.30	6832.83
Kuwait	3135.08	8486.39	1322.23	11544.16
Panel C: GDP per capita (current US$)				
UAE	6924.14	33729.85	25199.35	45758.91
Qatar	28183.72	43044.37	14120.30	88564.80
Bahrain	5707.70	15420.60	8528.98	24983.38
KSA	6470.46	12968.64	7204.70	25303.10
Oman	6119.53	11783.85	5988.80	22134.90
Kuwait	16283.87	26635.05	5407.97	55572.00

4.2. Theoretical Context of the Model

This research aims to analyze the effects of economic growth, and energy consumption on carbon emissions in the case of GCC countries. Following Alsamara, Mrabet, Saleh, & Anwar (2018) and Jalil and Feridun (2011), since both studies have used the linear model, which is easy interpretability of the coefficients and computational simplicity. For this paper, the linear econometric model will be used, which can be specified as follows:

$C_t = \beta_0 + \beta_1 e_t + \beta_2 y_t + \varepsilon_t$ …………………………………….. **Equation 1**

where:

- β_0 is constant
- β_1 and β_2 are coefficients
- C_t is CO_2 emissions per capita
- e_t is energy use per capita
- y_t is per capita GDP
- ε_t is the error term.

The lower-case letters in Eq. (1) indicate that all variables are used in their logarithmic form. Nonetheless, the classical EKC model is specified as below:

$C_t = f(y_t, y_t^2, e_t)$ …..……………………………………….. **Equation 2**

where the y_t^2 is the square of per capita GDP, so we can express it as following:

$CO_2 = f(GDP, GDP^2, EC)$ ……………………………………. **Equation 3**

Based on Eq. (3), we specify the log- linear relationships as follows:

$CO_2 = \beta_0 + \beta_1 EC + \beta_2 GDP + \beta_3 GDP^2 + \varepsilon_t$ ………………….. **Equation 4**

Chapter 5. Methodology

This research will adopt many econometric techniques that have followed by several studies such as Jalil and Feridun (2011), Zawada, et. al. (2014), and Alsamara, Mrabet, Saleh, & Anwar (2018). Regarding analyzing GDP per capita, CO_2 emission, and energy consumption by using Rstudio④ version 3.3. The sequence of these econometric techniques will start first by testing the existence of the cross-sectional dependence (CSD) for the three variables. Then, if the null hypothesis of the CSD test is not rejected, the panel unit root test can be implied to test the stationarity of the variables. After the integration of the data series at the same order, the causality test can be done between the variables to check the direction of the relationships. Lastly will come testing the EKC hypothesis by using Eq. (3) and Eq. (4). The details as following:

5.1. Cross Sectional Test

According to Alsamara, Mrabet, Saleh, & Anwar (2018), "ignoring country level cross-sectional dependence in empirical studies gives rise to loss of efficiency and insignificant results". Therefore, the first stage of analysis, it will be testing if the CSD for the three variables is significant in the data sample or not. By using the CSD test proposed by Pesaran (2004) test, it is a global test for testing the cross-sectional dependence in panel models. Pesaran CSD test is utilizing the average of the pairwise correlation coefficients $\hat{\rho}_{ij}$ from the residuals of the ADF regressions and is computed as below:

④ Rstudio: programming language for statistical computing and graphics.

$$CD = \sqrt{\frac{2T}{N(N-1)}(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij})} \quad \text{.................................... Equation 5}$$

5.2. Unit Root Test

Before testing the Granger causality test and the existing of the EKC hypothesis in GCC countries, first, the unit roots test all variables should be done. Unit root test is to test whether the time series variables are stationary or not. In different terms, the time series that do not have a unit root, it is a stationary time series with a constant over time statistical properties, which allows us to know the integration order of the three variables. This paper uses panel unit root tests that incorporate the presence of CSD.

The literature has developed a number of panel unit root tests, nonetheless this research will adopt three of these approaches which are commonly used; the Augmented Dickey-Fuller (ADF) by Dickey and Fuller (1979), Phillips-Perron (PP) by Phillips and Perron (1988), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests by Kwiatkowski et al. (1992). Both (ADF) and (PP) tests, had same the null hypothesis state that, there is a unit root present in a time series. On the other hand, the (KPSS) test had a contrary null hypothesis state that, the unit root is not present in a time series.

5.3. Causality Tests

Investigation of the causal relationship among the variables allows to have a good understanding of the significant issues and developed the appropriate policies. So that, many approaches have been applied in investigating the panel causality between the variables in the literature, especially the causality between the GDP per capita, CO_2 emissions, and energy consumption. This research will use the Granger causality test by Granger (1969), and Vector Auto-Regressive (VAR) test by Holtz-Eakin et al. (1988,1989).

5.3.1. Granger Causality Test

Granger causality test is commonly used in econometric studies to find the causality direction between variables. It tests if a one variable comes before another in the time series, or in other words, it measures whether one thing happens before another thing and helps predict it. The null hypothesis for Granger causality test is: x_t doesn't Granger-cause y_t. The following equation shows the hypothesis that current y_t is related to past lagged values of itself in one equation, and to the past lagged values of x_t and itself in anther equation:

$$y_t = a_0 + a_1 (y_{t-1}) \quad \text{...... Equation 6}$$

$$y_t = a_0 + a_1 (y_{t-1}) + a_2 (x_{t-1}) \quad \text{...... Equation 7}$$

Where:

- H_0: $a_2 = 0$
- H_1: $a_2 \neq 0$

5.3.2. Vector Auto-Regressive (VAR) test

The VAR test depend on the autoregressive (AR) model for more than one evolving variable, form in the following equation:

$$y_t = a_1 (y_{t-1}) + \varepsilon_t \quad \text{...... Equation 8}$$

In this model the current value of variable y depends on its own first lag, where $a1$ denotes its coefficient. In VAR test each variable has one equation, the current (time t) observation of each variable depends on its own lagged values as well as on, the lagged values of other variable. The Null hypothesis for VAR test is variable (1) doesn't cause variable (2).

5.4. Vector Error Correction Model

To test the presence of the EKC, the Vector Error Correction Model (VECM) was used. The VECM is, a Johansen's procedure to VAR by adding the error correction features to it. The procedure of it will be done as follows steps:

1. Estimate an unrestricted VAR
2. Testing cointegration by Johansen test
3. Form and analyze the VECM.

Forming the VECM will be as in Eq. (3) and Eq. (4):

$$CO_2 = f(GDP, GDP^2, EC) \quad \text{.......................................} \quad \textbf{Equation 3}$$

$$CO_2 = \beta_0 + \beta_1 EC + \beta_2 GDP + \beta_3 GDP^2 + \varepsilon_t \quad \text{...................} \quad \textbf{Equation 4}$$

When $\beta_2 > 0$ and $\beta_3 < 0$ it indicates that there are an inverted U-Shape (EKC), and $\beta_2 < 0$ and $\beta_3 > 0$ it indicates that there is a U-shaped relationship between the two variables ,as indicated by Akbostanci et al. (2009).

Chapter 6. Empirical Results

6.1. Finding from CSD Test

As shown in Table (2), the Pesaran (2004) CSD test for the GDP per capita variables rejects the cross−sectional independence hypothesis at the 1% significance level. On the other hand, for the CO_2 emission and energy consumption, the null hypothesis was rejected at the 5% significance level. In essence, the CSD exists across GDP per capita, the CO_2 emission and energy consumption, same results had been indicated by previous studies such as Alsamara, Mrabet, Saleh, & Anwar (2018).

Table 2 Cross-Sectional Dependence Tests results

Variables	Pesaran CSD Test (p−value)
GDP	3.85E-09***
CO_2	0.04334**
EC	0.0235**

*Significant at 10% significance level
**Significant at 5% significance level
***Significant at 1% significance level

6.2. Finding from Unit Root Test

Table (3) shows that the GDP per capita, CO_2 emission and energy consumption considered in this research are non−stationary in levels, same as Basarir and Arman (2013), Bader, Y., & Ganguli, S. (2019), and Alsamara, Mrabet, Saleh, & Anwar (2018). However, the three variables are stationary in their first differences, this for both (ADF) and (KPSS) tests. On the other hand, the GDP per capita, CO_2 emission and energy consumption in the (PP) test were stationarity at constant and trend model. Based on these results, the rests of the econometric test can proceed.

Table 3 Results of Unit Root Test

Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests

Country	GDP		EC		CO_2	
	Level	1st difference	Level	1st difference	Level	1st difference
UAE	0.07	0.06***	0.17	0.10***	0.07	0.05***
Qatar	0.19	0.10***	0.19	0.09***	0.20	0.13***
KSA	0.22	0.08***	0.17	0.08***	0.13	0.07***
Oman	0.20	0.11***	0.15	0.08***	0.12	0.13***
Bahrain	0.17	0.07***	0.20	0.09***	0.08	0.07***
Kuwait	0.09	0.09***	0.19	0.07***	0.13	0.07***

Phillips-Perron Unit Root (PP) Test

Country	GDP		EC		CO_2	
	Constant Model	Trend Model	Constant Model	Trend Model	Constant Model	Trend Model
UAE	-5.2646***	-5.1466***	-6.2765***	-6.0924***	-5.6849***	-5.5528***
Qatar	-5.6698***	-5.7695***	-4.5252***	-4.5012***	-3.6469**	-3.6836**
KSA	-4.8086***	-5.3116***	-8.4123***	-8.2452***	-6.0166***	-5.9827***
Oman	-6.6743***	-6.7703***	-3.7528***	-3.6732**	-4.4624***	-4.3053**
Bahrain	-5.3153***	-5.3895***	-5.3207***	-5.6429***	-5.6849***	-5.5528***
Kuwait	-4.6068***	-4.4594***	-5.674***	-6.6831***	-7.6755***	-8.4467***

Augmented Dickey-Fuller Test (ADF)

Country	GDP		EC		CO_2	
	Level	1st difference	Level	1st difference	Level	1st difference
UAE	-0.85	-4.23***	-0.68	-4.27***	-2.62	-4.21***
Qatar	0.14	-4.31***	-1.82	-2.55*	-2.52	-4.20***
KSA	0.51	-3.75***	-0.12	-3.09***	-0.97	-3.09**
Oman	0.07	-3.69**	-0.82	-5.12***	-0.98	-7.12***
Bahrain	0.24	4.11***	-1.72	-3.47**	-2.10	-4.04***
Kuwait	-1.15	-3.91 ***	-2.56	-3.66**	-2.82*	-3.42**

* Significant at 10% significance level ** Significant at 5% significance level

*** Significant at 1% significance level

6.3. Finding from Causality Tests

The results from the Granger causality and VAR are presented in Table (4) and Table (5), which shows a slight difference between the results of both tests. However, in both tests the results indicate the absence of any directional causality relation in Kuwait, and Qatar was the only country with a unidirectional causality relation going from energy consumption per capita to CO_2 emission.

Table 4 Results of Granger Causality Test

Country	GDP → EC		EC → GDP		CO_2 → EC		EC → CO_2		GDP → CO_2		CO_2 → GDP	
	P-Value	Signif %	P-Value	Signif %	P-Value	Signif %	P-Value	Signif %	P-Value	Signif %	P-Value	Signif %
KSA	0.04	5%										
Qatar									0.02	5%		
UAE	0.07	10%	0.02	5%			0.02	5%				
Oman	0.01	5%	0.01	1%	0.00	1%	0.02	5%			0.03	1%
Bahrain	0.04	5%										
Kuwait												

The Granger causality results indicate the presence of a unidirectional causality relation going from GDP per capita to energy consumption per capita in KSA, Oman, and Bahrain at the 5% significance level, and at the 10% significance level for UAE. Same results were come from the VAR test, since UAE and Oman had a unidirectional causality relation going from GDP per capita to energy consumption per capita at the 1% significance level. likewise, KSA, and Bahrain has the same unidirectional causality relation but at the 10% significance level.

After all, the results from the causality test shows that in four of the GCC countries the growth in GDP per capita causes the growth in energy consumption per capita. From these results, implies that policies in the GCC countries can be designed to conserve energy, increase efficiency in energy consumption, and to control CO_2 emissions without much concern about its effect on their GDP growth.

Table 5　Results of Vector Auto-Regressive (VAR) test

Country	GDP → EC		EC → GDP		CO_2 → EC		EC → CO_2		GDP → CO_2		CO_2 → GDP	
	P-Value	Signif %	P-Value	Signif %	P-Value	Signif %	P-Value	Signif %	P-Value	Signif %	P-Value	Signif %
KSA	0.07	10%	0.06	10%			0.03	1%				
Qatar									0.00	1%		
UAE	0.03	1%										
Oman	0.01	1%	0.00	1%	0.00	1%	0.03	1%			0.02	1%
Bahrain	0.07	10%										
Kuwait												

6.4. Findings from EKC

The estimated results after testing the VECM for the GCC countries among the GDP per capita, CO_2 emission and energy consumption are presented in Table (6). Testing the existing of the EKC hypothesis had a different result across the six countries can be divided into three categories since the EKC did not holds in all countries and did not found at all in other. The detailed result of each category will be expounded as follows:

Table 6 Results of VECM

Country	GDP	GDP^2
KSA	-5.420	0.121
Qatar	-14.01	2.052
UAE	0.004	-0.796
Oman	0.230	0.080
Bahrain	-0.023	0.462
Kuwait	-2.302	1.721

6.4.1. EKC hypothesis not confirmed:

When the results significantly revealed that GDP per capita is negatively related to CO_2 emissions per capita (or the coefficient of GDP had a negative value), on the other hand the GDP2 is positively relatively related to CO_2 emission per capita (or the coefficient of GDP2 had a positive value). This case indicating U-shape relationship between the two variables, since $\beta_2 < 0$ and $\beta_3 > 0$.

Table (6) shows that, there are four countries had U- shape relationship which are, Qatar, Saudi Arabia, Kuwait, and Bahrain. This means the growth in the GDP per capita in those countries reduces the CO_2 emissions per capita till a certain income level, which further it the growth in the GDP per capita is increasing the CO_2 emissions per capita. In other words, the past CO_2 levels have no significant impact on present ones. Moreover, the GDP per capita has a negative and significant impact on CO_2 at the low levels of income, and it has a positively and significantly impact on CO_2 at the higher levels of income.

This proves that the non-existence of the EKC since the GCC countries' economy is mostly dependent on hydrocarbons for its income. Most of the increase in GDP per capita is caused by higher oil and oil-related production and refining, which are highly polluting. In addition, this result can compare in a country-based result with the findings of Burcu Ozcan (2013), as its sample if for 12 of the Middle East countries. This study found the same results for Saudi Arabia, Kuwait, and Bahrain, but not for Qatar since it is not included in their sample.

6.4.2. EKC hypothesis confirmed:

When the results significantly revealed that GDP is positively related to CO_2 emissions (or the coefficient of GDP had a positive), on the other hand, the GDP2 is negatively relatively related to CO_2 emission (or the coefficient of GDP2 had a negative). This case indicates that there is an inverted U-Shape confirming EKC hypothesis, since $\beta_2 > 0$ and $\beta_3 < 0$.

The results of VECM shows that the UAE it is the only country over the GCC countries, that had confirmed the validity of EKC hypothesis, by having a positive coefficient of GDP per capita (0.004) and negative coefficient of GDP^2 per capita (−0.796). This result is also in line with studies in the literature that related to the Middle East, such as Burcu Ozcan (2013). These results could be attributed to the fact that the UAE has taken steps to manage the CO_2 emission. However, these results could not compare with the studies of Bader, Y., & Ganguli, S. (2019), Alsamara, Mrabet, Saleh, & Anwar (2018), and Basarir and Arman (2013).

6.4.3. EKC hypothesis not found:

The results are insignificant if both coefficient of GDP and GDP2 are neither positive nor negative together, leading to no results regarding the validity of EKC. According to Basarir and Arman (2013), and Bader, Y., & Ganguli, S. (2019), Oman's coefficients were insignificant. Which it is a similar finding in this research, both coefficients positively related to CO_2 emissions since the coefficient of GDP per capita is (0.230), and the coefficient for GDP2 per capita is (0.080). On the other hand, these results could not compare with the results of other studies such as Alsamara, Mrabet, Saleh, & Anwar (2018) since they found that EKC is not holding for Oman, likewise, was the results of Burcu Ozcan (2013).

From testing the EKC hypothesis using VECM, it can be safely concluded that there is no presence of EKC in the GCC as a whole since there is only one country of the six GCC countries had shown the inverted U-Shape. There are many reasons could be behind the non-existence of the EKC, such as lack in the economic diversification. Since, the GCC countries are mainly dependent on oil and natural gas-related products as the main source of its revenues since the oil boom in the 1970s, which are the leading causes of CO_2 emissions.

High emissions and non-existence of the EKC may also be due to a lack of awareness regarding and indifference to the harmful impact of environmental pollution. While it is likely the low-priced for fuel and the associated products in the GCC countries had a, in all of the sectors industrial, commercial, and residential contributed to the U-shaped curve results for the EKC test. Charts in figure (10) and figure (11)⑤ show electricity tariffs and fuel prices of the six countries comparing to one of the large producers of oil and gas, which is the United States (IEA, 2018).

The electricity tariffs are low comparing to the United States, since it is one of the largest oils and gas producer in the world (IEA, 2018). Regarding the fuel prices for both Gasoline and Diesel is also extremely law in the GCC countries comparing to the international market. Even though the United States had high total final energy consumption and high total primary energy supply compared to the GCC countries, on the other hand, the, their per capita emission is less than the GCC countries.

⑤ Source: Utilities, (EIA, 2018)

Eventually, the empirical results can be concluded as the data for the six countries were stationary after taking the first differences. Moreover, after running the causality tests, it found a common unidirectional relationship in between the six countries which are going from GDP per capita to energy consumption. Furthermore, it found that the UAE was the only country in the GCC, which had an inverted U-shape curve to support the EKC hypothesis.

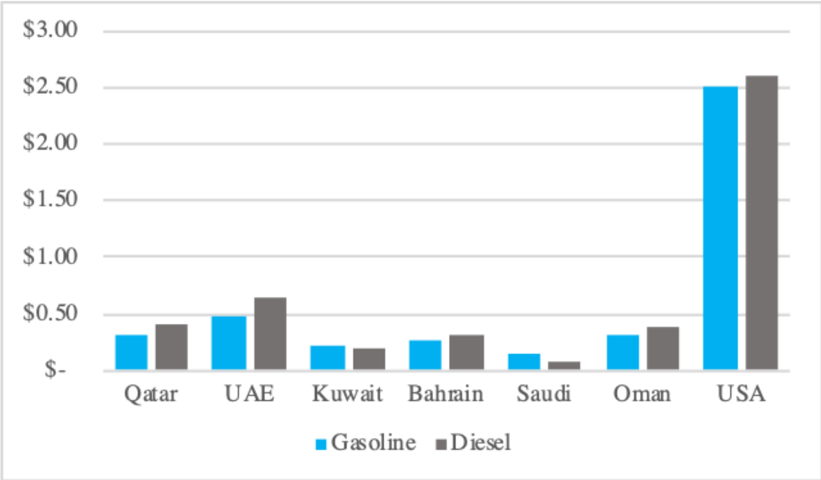


Figure 11 Fuel Prices for the GCC countries Vs. USA

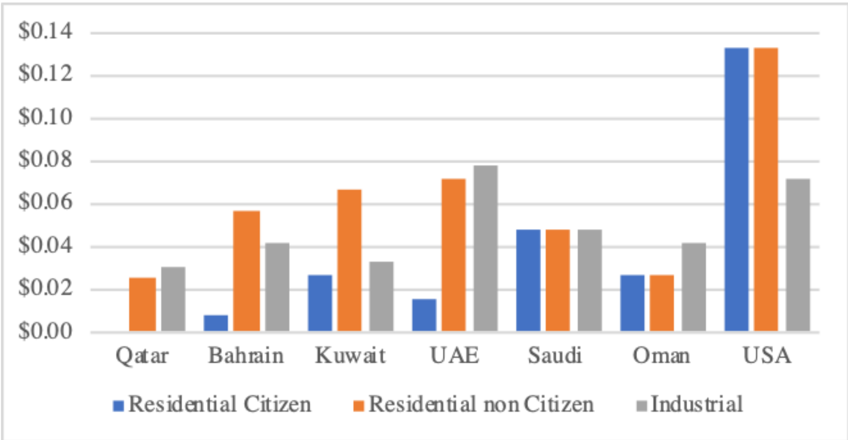


Figure 10 Electricity Tariffs for the GCC countries Vs. USA

Chapter 7. Policy Implications

This chapter will focus on the recommended policies for GCC countries depending on the findings from the econometric tests in the previous chapters. Therefore, the recommended policies can be classified into two categories: policies related to the causality test results and, on the other hand, policies related to the results of testing the validation of the EKC hypothesis.

7.1. Over the literature

Despite the fact that the literature related to GCC energy consumption, CO_2 emissions, and economic growth nexus is limited, the available literature had proposed numerous policies to help the GCC countries to reduce the CO_2 emissions, and increase the energy efficiency. It will start with energy prices, which were the main focus of several papers since the energy price in the GCC countries is relatively lower than most of the other developed countries, as mentioned before. Mohammed R. (2009) recommends a national tax program and pricing policies since some of the GCC countries offer, for example, electricity free of charge to the citizens. The same recommendation was introduced by Mohsen, M. (2006) and Mohamed El Hedi and Adel Ben Y. (2012). Additionally, Mohsen M. (2006) mentioned a subsidy reform, since the GCC countries, like other oil and gas producers, have a high subsidy rate. The subsidies for energy explain the high energy intensity in these countries; therefore, reform policy would control wasteful use and energy intensity.

The second recommendation in the literature was using renewables since the GCC countries have a high renewable energy potential, especially for solar energy. Alsamara, M. 2018, says that controlling the environmental pollution in the GCC countries depends on finding alternatives for electricity generation, such as solar power and nuclear energy. Under the same recommendation, Mohamed El Hedi and Adel Ben Y. (2012) propose that using the neglected solar technologies in the GCC countries can solve high electrical consumption, especially in water desalination. The GCC countries depend on desalination as the primary source of water since the renewable water resources in the region are considered to be the least secure in the world. Moreover, according to IRENA (2019), the water demand in the GCC countries is expected to increase fivefold by 2050 with the current fastest-growing population.

Public awareness of energy use was one of the introduced recommendations, due to the high domestic consumption of the energy because it is low prices. Helmi H. and Rashid S. (2014), in studying "The nexus between electricity consumption and economic growth in Bahrain," found that the improvement in the standards of living in Bahrain over the past decade has driven energy demand. Therefore, public education programs can reduce the excessive and wasteful use of energy power as recommended by Alsamara, M. (2018).

7.2. Related to the causality test

After studying the causality relationship between energy consumption, CO_2 emission, and economic growth, the most repeated unidirectional causality relationship among the six countries was going from the GDP per capita toward the energy consumption per capita. Based on this unidirectional causality relationship, the energy conservation policies can be applied without affecting the GDP growth. For this study, the recommended policies related to energy conservation will be categorized by sectors since

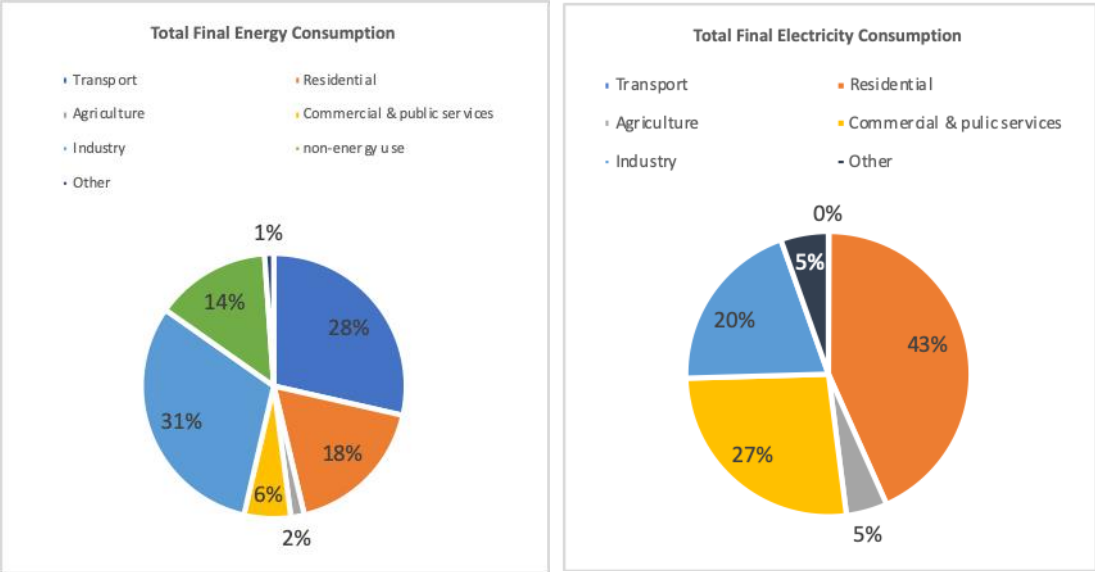


Figure 12 Total energy and electricity consumption in GCC 2016

each sector participates differently regarding energy efficiency. The following will explain the possible development policies to improve the energy efficiency in significant sectors of GCC countries. Figure (12) shows the total energy consumption and the total electricity consumption since it is a leading form of energy consumption.

7.2.1. Residential Sectors

As mentioned in the literature in the previous section, the domestic demand is increasing with a wasteful usage of energy consumption and its forms. Therefore, it can be found that the residential sector is holding the highest share over the total electricity consumption by 43%, and 18% of the total energy consumption as presented in Figure (12). The main reasons behind the inefficient consumption are the low energy prices in all their forms as shown in Figures (10) and (11), and the lack of awareness of the residents about energy efficiency. The recommended policies for the policymakers regarding the residential sector are as follows:

<u>Subsidy and price reform</u>

"Prices for energy products in the most of oil and gas producer countries are well below the value that could be obtained for these commodities on the international market, and the fossil fuel consumption subsidies, in most cases, represent foregone revenue rather than actual budgetary payments" (IEA, 2018). For example, the total value of Saudi Arabia's subsidies was around $38 billion in 2017, which came to be the third-largest value of subsidies in the world, as presented in Figure (13). Consequently, reducing the high subsidy rate and increasing the energy prices in

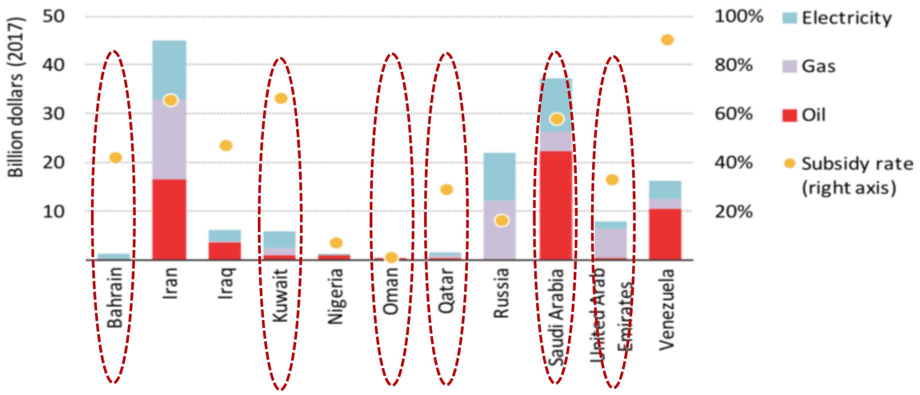


Figure 13 The Subsidy rate & its value in USD 2017 (IEA,2018)

one move would indirectly encourage the residents to increase the energy efficiency of their usage and lower their energy consumption.

<u>Increase the public awareness</u>

Raising residents' awareness of energy-efficient practices by introducing new technologies to encourage the residents and citizens to make full use of energy efficiency, such as smart meters and light-emitting diode (LED) lighting (IREA 2019). Getting the public attention could be done by using social media and government announcements to enlighten them about important topics related to energy consumption such as energy efficiency, renewable energy, and air pollution.

7.2.2. Commercial Sector

Commercial buildings such as malls, hotels, and hospitals have a high energy consumption due to the long operating hours and their need to maintain cooling demand to keep their users satisfied. For this reason, the commercial sector holds shares of 27% from the GCC's total electricity consumption and 6% of its total final energy consumption. Improving commercial energy efficiency will not only have a positive impact on the building owners but also open new opportunities for providing jobs since the energy management industry is an expanding market. In order to improve energy efficiency in the commercial sector, governments and policymakers can consider adopting the following policies:

Fiscal incentives and penalty system

Incentive programs can apply a discount rate on the monthly bills for the buildings with the highest performance. On the other hand, a penalty system can be applied by the government on the buildings with the lowest performance and over-consumption. This incentive and penalty system will motivate the building owners to save more and aim for better, more efficient performance.

Information dissemination

Any business wanting to improve its energy efficiency needs easily accessible information on how to get going (Mark R., 2016). Energy reporting and information dissemination to the public market will help building owners know the ability of their building and how it can save energy, carbon, and cost. Energy reporting can be done by public marketing campaigns to promote the successful cases and with the highest-performing buildings.

7.2.3. Industrial Sector

Worldwide, the industrial sector is the largest consumer of energy, and this is the same case for the GCC countries since they consume 31% of the total final energy consumption and 20% of the final electricity consumption as it is presented in Figure (12). In order to improve the energy efficiency in the industrial sector, the recommend policies for the commercial sector such as the information dissemination and incentive programs can be applied too. Moreover, the policymakers can consider additional policies as follows:

ISO 50001

ISO 50001 is a standard created by the International Organization for Standardization (ISO) as a guide for establishing and improving an energy management system. It aims to help the organization follow a systematic approach in order to improve their energy efficiency, energy security, energy use, and consumption. Therefore, incentivizing the organizations to adopt the ISO 50001 will eventually help the industrial sector to continually reduce its energy use, energy costs, and greenhouse gas emissions.

Research and development

Research and development (R&D) of technologies according to Price, L., & Worrell, E. (2000) can be defined as "creative work undertaken on a systematic basis to increase the stock of knowledge, including knowledge of people, culture and society, and the use of this knowledge to devise new applications." However, the central aspect of investing in R&D for the GCC countries is their adaptation to technologies suits the local market and conditions. The operating environment in this region is different from that of industrialized countries due to its higher temperatures and humidity, which require different energy efficiency solutions.

7.2.4. Transportation Sector

The transportation sector is a significant consumer of total final energy in the GCC countries after the industry, residential, and commercial sectors since it is holding approximately 29% of the GCC's total final energy consumption and almost 0% of the total electricity consumption. Therefore, the main recommended policy is to plan for electric vehicle (EV) adoption in the GCC countries by building a network of EV charging stations to align with regular main routes.

7.3. Related to EKC test

After studying the validation of the EKC hypothesis for the six countries of the GCC region, it shows that the UAE is the only country that holds the inverted U-shaped curve of the EKC hypothesis. According to this result, the following section will include the reasons behind the success of the UAE to hold the EKC curve and the recommendation for the rest of the GCC countries based on this success.

7.3.1. UAE Case

The GCC countries share a common culture, history, economic base, and consumer behavior; however, the UAE is taking the lead over the other five countries in many fields. For example, the UAE has made its mark in the world as a leading tourism destination; hence, Dubai has become not only a trading hub but also one of the international tourism destinations for leisure and business travelers. The following will explain in more detail how UAE is different from the other GCC countries:

Diversify the economy

Among the GCC countries, the UAE has greater success in diversifying its economy. The services sector has become dominant in UAE's economy with a growth rate of 5.8% per year on average since 2000, as presented in Figure (14). This growth started after the establishment of its world-class airlines, such as Emirates Airways and Etihad Airways, and these airlines are used not only for travel but also for shipping. Currently, the services sector is taking over the industrial sector, which includes the oil and gas sector, since the average rate of growth of the services sector has become higher than the average rate of growth in the industry by 2.3 percentage points (IEA, 2018).

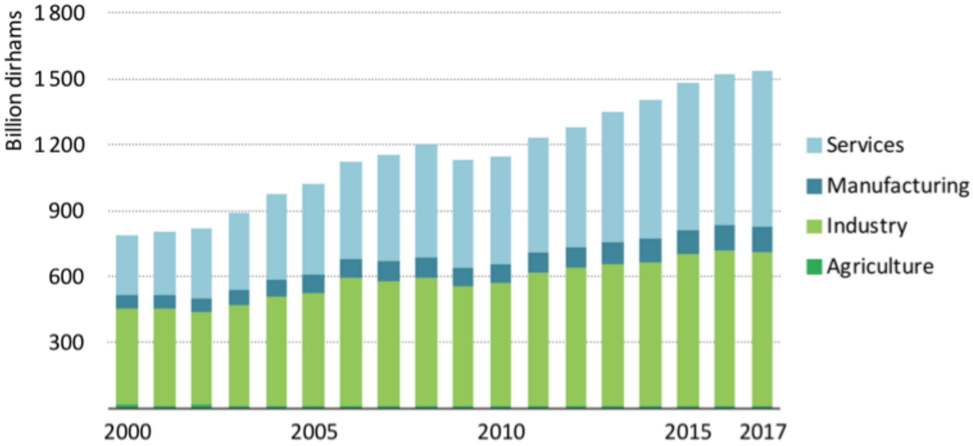


Figure 14 Structure of the UAE economy (IEA,2018)

Energy mix

The UAE is in the lead regarding adopting renewables in its energy mix, and it is also the largest market for renewables among the GCC countries, as shown in Figure (15). UAE has launched a green growth strategy in its 2021 vision, which focuses more on relating its sustainable development goals to renewable energy. Therefore, UAE is the largest solar market by hosting “close to 79% of the installed solar PV capacity in the GCC and has managed to attract some low-cost solar PV projects without offering subsidies” (IRENA, 2019).

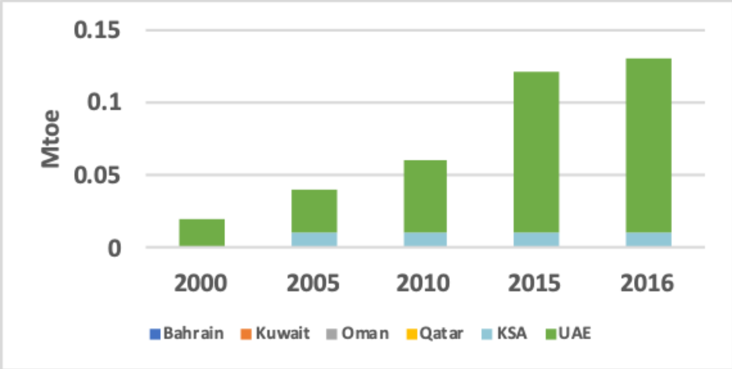


Figure 15 Total primary energy of Renewables, (IEA,2018)

Figure (16) shows the investment of the six countries regarding the renewables, and the highest investment was started in 2011 by UAE with $765 million invested in 100 Megawatt Shams 1 CSP plant. From 2015 to 2017, UAE had a large−scale investment in solar projects named “Mohammed Bin Rashid Al Maktoum Solar Park,” which has four phases, taking a total area 77 km2, and costs $3.2 billion (IRENA, 2019). UAE had the highest share of investment in renewables among the GCC counties, which makes it in the lead of adopting renewables.

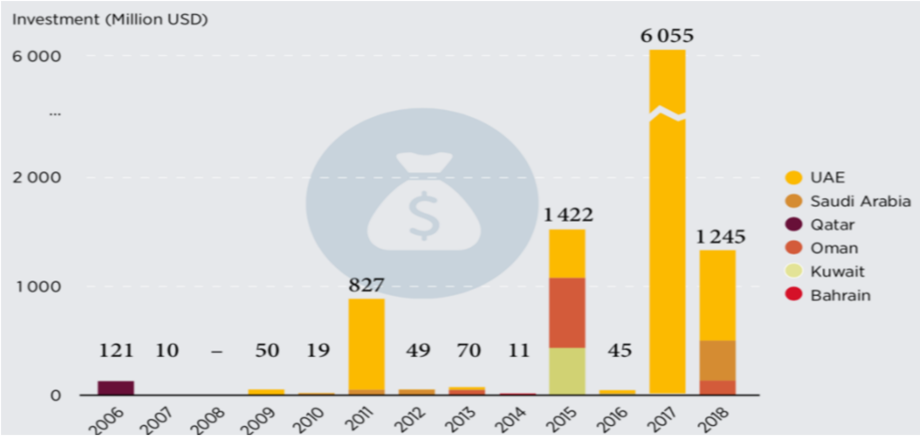


Figure 16 GCC's investment in renewables (IRENA,2019)

Price Reforming

Lastly, UAE was the first among the GCC countries to remove the subsidies over the energy prices. The UAE government does not impose a levy income tax; nevertheless, it had introduced a 5% value-added tax (VAT) (IEA, 2018). Removing the subsidies and increasing the prices were not only for the energy sector but also included the water tariffs. In this region, water efficiency is related to energy efficiency, since most of the water production involves desalination and energy-intensive processes.

In Dubai, water tariffs have increased by removing the subsidies over its prices. In a Dubai Electricity and Water Authority (DEWA) report in 2017, they have reported significant savings as a result of removing these subsidies over electricity and water tariffs, as shown in Figure (17).

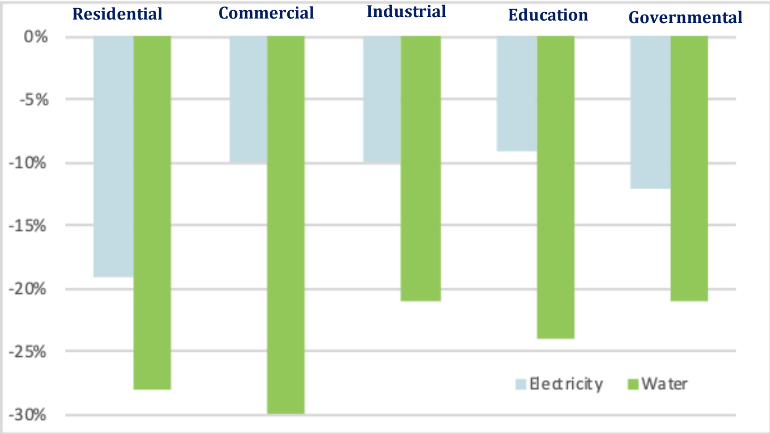


Figure 17 Savings in electricity and water sectors 2009–2016

7.3.2. Recommendations

Based on the last section, the UAE had shown a successful pathway to improving its energy efficiency through significant savings in the electricity and water sectors. Since the UAE shares the same market and economic features as the rest of the GCC countries, following their path will be a tested method of achieving higher energy efficiency. The following section includes details of the approaches that the UAE should adopt.

<u>Diversify the Economy</u>

The UAE's reliance on external revenue is a crucial consideration. Domestic sources of revenue imply productive sectors within the national economy. If it is high enough, however, external revenue can support an economy even without a strong and productive domestic sector (Beblawi and Luciani, 1987). Under these circumstances, there is a risk that the functioning of such a state will focus more on the distribution and allocation of rents than on the creation of the conditions required for enterprise, which can lead to a restricted and undiversified economic structure (IEA, 2018).

In terms of oil-producing countries, not all large producers are net exporters of oil and gas. Likewise, not all net exporters rely on the revenue from oil and gas; this is the case of Canada and Kuwait since both countries had similar levels of net exports of oil (at around 2.5 million barrels per day (mb/d)) in 2017. On the other, these exports had a different role in the economies of both countries since they account for more than 90% of total exports in Kuwait but less than 15% of total exports in Canada. Moreover, the revenue from oil and gas accounts for 90% of fiscal revenue in Kuwait but less than 5% in Canada as it appears in Figure (18) (IEA, 2018).

Diversifying the economy will not only open up more opportunities for a more varied range of business sectors and industries but also would reduce the risk of reliance on oil and gas revenue since the fluctuating oil prices and changes in the global oil-market reflect on the GDP. Figure (19) shows how any drop in the oil prices will affect the GDP, such as in 2009, the total GDP per capita for the GCC countries has decreased by 26%. Similarly, the drop in the oil price 201e has its reflection on the GDP per capita in 2015 to decrease by 20%. On the other hand, any increase in the prices will have a positive effect on the GDP per capita as was the case in 2010 and 2011.

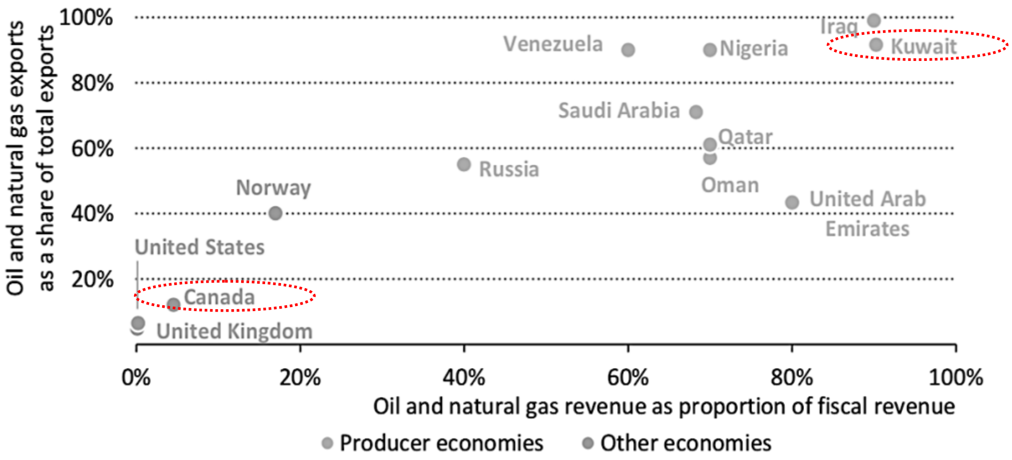


Figure 18 Oil and gas net trade and production 2017 (IEA,2018)

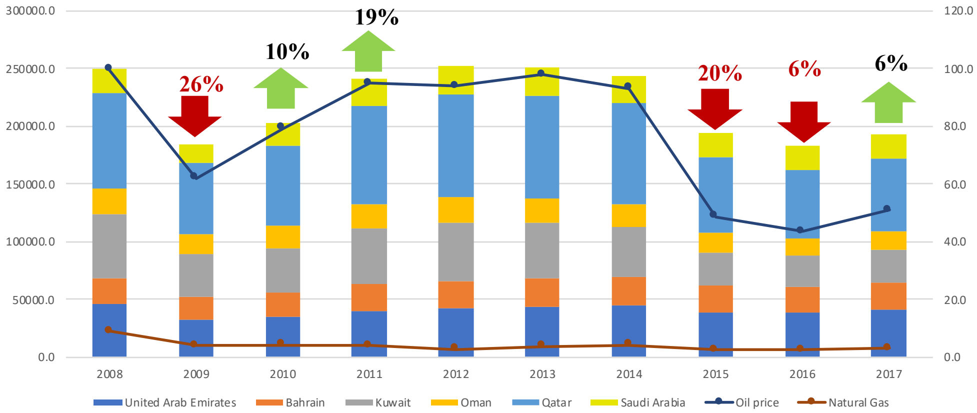


Figure 19 GDP per capita & oil and gas prices (2008-2017)

Energy Mix

The GCC countries can diversify their energy mix by increasing the share of renewables in power generation since the region has renewable energy potential, especially for solar photovoltaic (PV) generation and wind resources. According to IRENA (2019), the GCC countries had the best solar irradiation rates in the world for both concentrated solar power (CSP) and solar photovoltaic (PV). The global horizontal irradiance (GHI) map⑥in Figure (20) indicates that the GCC countries had a solar PV resource, especially in the north–western and central regions of Saudi Arabia and the southwestern region of Oman (IRENA, 2019).

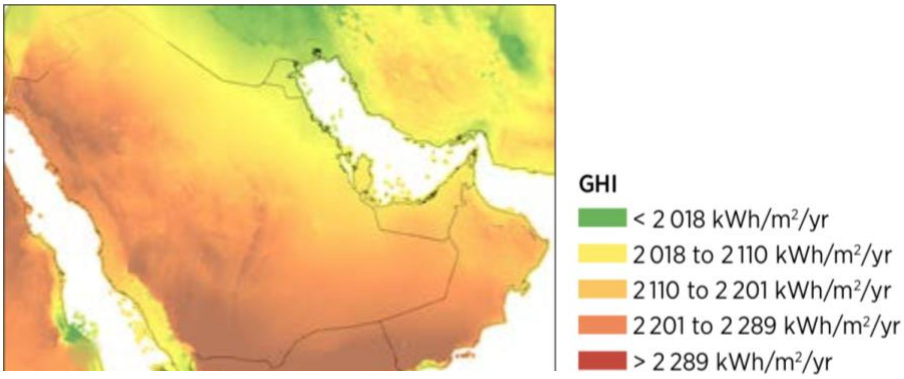


Figure 20 The (GHI) map, (IRENA,2019)

On the other hand, countries such as Kuwait, Oman, and Saudi Arabia have very decent wind resources. The GCC's average annual wind speed mapped in Figure (21) indicates that a large area in the GCC region has wind resources above the 7.5 m/s. Despite the availability of such sources, it is not fully utilized by the GCC countries since there are no undertaken essential steps towards renewable energy adoption to expand solar and wind power.

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⑥ It extracted from the Global Atlas tool by " IRENA's web- based Global Atlas software (https://irena.masdar.ac.ae/)"

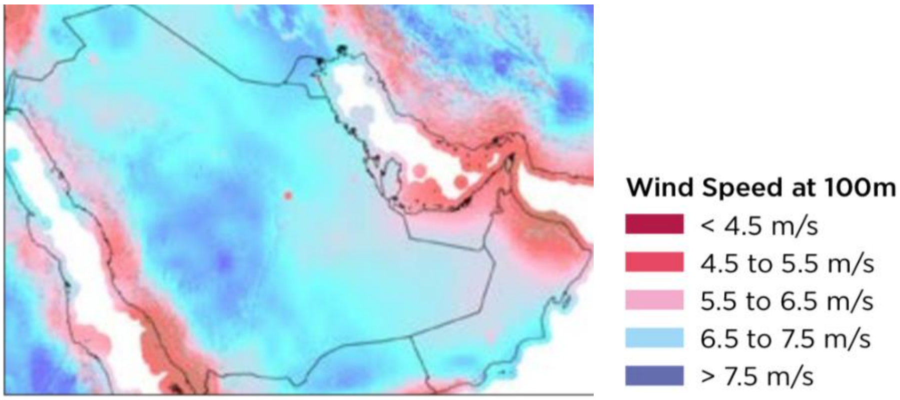

Figure 21 Wind Map, (IRENA,2019)

"Energy efficiency is also a prime driver of the integration of variable renewable energy" (IRENA, 2019). Therefore, to accelerate the adoption of demand-side management, the government can introduce some energy efficiency measures such as thermal and electric storage and smart appliances. GCC governments should show additional attention to improve energy efficiency in all the economy sectors by adopting new targets to work on energy and water consumption reduction. Reaching these targets can be done using incentives programs for electric and public transport, setting a fuel efficiency standard, and reforming the energy and water prices. Building a consistent framework to mandate the implementation of new regulations will assist GCC countries in achieving their targets and reduce CO_2 emissions.

Figure (22) shows that the total CO_2 emissions in the GCC countries from 1971 to 2016 are from fuel combustion, and it is reasonable since it is the primary source for energy production and the base of their economy. Increasing energy efficiency will eventually help in reducing CO_2 emissions. For example, in 2016, the electricity consumption alone was holding 44% of the total CO_2

emissions, and electricity production itself depends on oil by 29% and gas by 71%. Therefore, increasing electricity efficiency and reducing its consumption among all the economy sectors will reduce its production, save more oil and gas, and reduce consumption-related CO_2 emission.

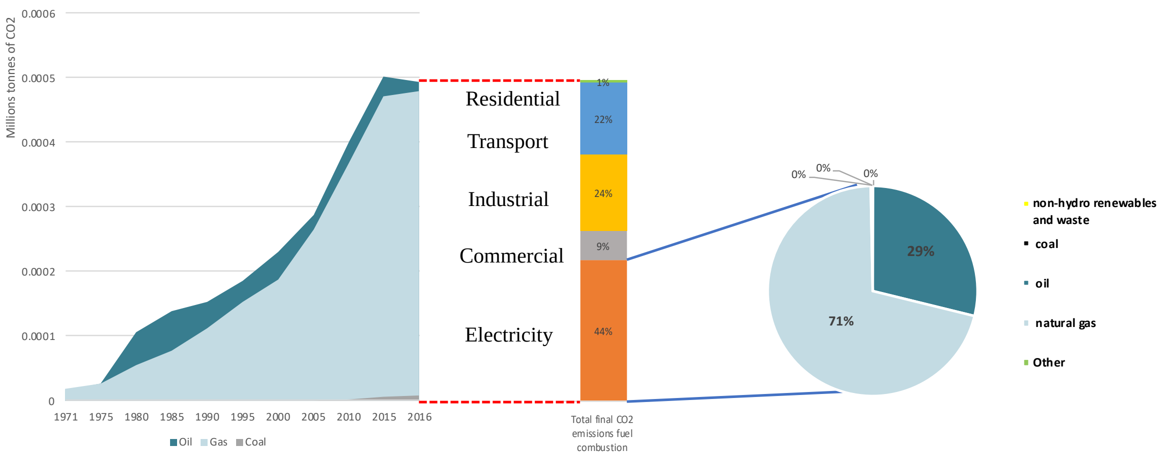

Figure 22 Total CO_2 emissions, per sector 2016

Chapter 8. Conclusion

The GCC countries are witnessing strong economic growth and fast development over the last decades, which is followed by massive increases in environmental pollution and energy consumption. This study has examined the validity of the EKC hypothesis in GCC countries by using panel data over the 1990–2014 period. The distinguishing features of this paper first combine the EKC testing and causality test in one framework, and secondly, use two econometric estimation techniques, the Granger causality test and the VAR test, in developing a panel causality test.

By using VECM to investigate the validity of the EKC hypothesis, the estimated results found that the EKC hypothesis was only valid in the UAE among the GCC countries. This result could be attributed to the fact that the UAE has taken steps to manage the CO_2 emissions, such as making proper utilization of the potential renewable energy in the region. After that comes the causality test. There were unidirectional causality relations going from GDP per capita to energy consumption per capita in most of the six courtiers. On the other hand, the causality relation going from energy consumption to economic growth wasn't common in between the six countries. Since the relation direction goes from the GDP per capita to energy consumption per capita not the reverse direction, this indicates that energy conservation policies, such as limiting energy consumption, increasing energy efficiency, and controlling CO_2 emissions, are likely to have no adverse effect on the output growth of the GDP.

This paper has presented some significant policy implications for the GCC countries to help control environmental pollution and energy consumption. For instance, they need to increase their investment in clean technologies and alternative sources of electricity such as wind and solar power, which can achieve the goal of transition to a low carbon economy (Weller S., 2011). On the other hand, government action cannot solve the situation alone; therefore, public education programs would raise awareness regarding the environmental pollution problem. These programs would help in educating the public in GCC countries about energy efficiency and how to reduce the wasteful use of energy. Lastly, following the lead of UAE in adopting several methods that have been mentioned above to control environmental degradation will eventually end with the same success for the rest of the GCC countries.

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Appendix

Appendix (I): Literature View

EKC's Literature Summery

Authors, Publication year	Country	Data Period	Empirical Methodology	Empirical Results
Hamit-Haggar (2012)	Canada	1990-2007	VECM	Inverted U
Fodha, M.& Zaghdoud, O. (2010)	Tunisia	1961-2004	Cointegration test of Johansen, VECM, and Granger causality test	Inverted U
Ang, J. B. (2007)	France	1960-2000	ARDL bounds test and VECM	Inverted U
Pao, H., & Tsai, C. (2011)	Brazil	1980-2007	Gray model (GM) and VECM	Inverted U
Artaxo, P. (1998)	23 countries	1974-1989	Panel cointegration analysis	U- shaped
Jalil and Feridun (2011)	China	1953-2006	VECM and Granger causality	Inverted U
Martínez-Zarzoso & Bengochea-Morancho (2004)	22 OECD	1975-1998	Pool mean group (PMG) estimation	N- shapes

Literature studying the EG- EC nexus

Authors, Publication year		Country	Data Period	Empirical Methodology	Empirical Results
Single Country					
Kraft (1978)		USA	1947–1974	Granger causality	EG → EC
Abosedra and Baghestani (1989)		USA	1947–1987	Co-integration and Granger causality	EG → EC
Stern (2000)		USA	1948–1994	Co-integration and Granger causality	EC→ EG
Ghali and El-Sakka (2004)		Canada	1961–1997	Co-integration, VEC, Granger causality	EC←→ EG
Altinay and Karagol (2004)		Turkey	1950–2000	Hsiao's version of Granger causality	EC ---- EG
Multi Country					
Soytas and Sari (2003)	7 countries	Argentina	1950–1992	Co-integration and Granger causality	EC ←→ EG
		Italy, Korea			EG→ EC
		Turkey, France, Japan, Germany			EC→EG
Mishra et al. (2009b)	9 Pacific Island countries	Fiji, French Polynesia, Kiribati, New Caledonia, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu	1980–2005	Granger causality	EC ←→ EG

Literature studying GCC countries

Authors, Publication year	Variables	Empirical Methodology	Empirical Results
Cusality			
Al-Iriani (2006)	EC & EG(GDP)	Panel Cointegration	(EG)GDP→ EC
Al-mulali and Chor Foon Tang (2013)	EG(GDP), EC	Panel data analysis, Granger causality	(EG)GDP→ CO_2
Mohammad Salahuddin (2014)	EC, EG(GDP), CO_2	Panel data analysis, Granger causality	EC←→CO_2 (EG)GDP→ EC
Hussain Ali Bekhet (2017)	EC, EG(GDP), CO_2, and FD	ARDL testing, Granger causality	CO_2 →EC (Qatar, UAE, KSA) CO_2←→EC (Kuwait, Oman) EC→EG
EKC			
Bader, Y., & Ganguli, S. (2019)	CH_4, CO_2, GDP	Panel data analysis, Granger causality	EKC not valid in UAE, and Kuwait
Both			
Alsamara, M., Mrabet, Z., Saleh, A. S., & Anwar, S. (2018)	SO_2, CO_2, GDP	Panel data analysis, Granger causality	EKC not valid in Oman, Bahrain and Kuwait

Literature studying the three variables

Authors, Publication year	Country	Data Period	Empirical Methodology	Empirical Results
Burcu Ozcan (2013)	12 MENA Countries	1990-2008	FMOLS & ARDL	KEC holds in 5 countries only (EG) GDP→ EC→ CO_2
James B. Ang (2007)	France	1960-2000	Cointegration	KEC holds (EG) GDP→ CO_2
Saboori and Soleymani (2011)	Iran	1970-2007	ARDL	Doesn't hold for EKC EC → CO_2

Appendix (II): Data for GCC's Current Situation

Total final consumption of energy (Mtoe)

	1973	1980	1990	2000	2005	2010	2015	2016
Bahrain	0.72	1.27	2.09	3.05	4.23	5.12	6.29	6.36
Kuwait	3.93	6.26	3.95	8.15	12.17	15.05	18.14	19.18
Oman	0.09	0.55	1.84	3.04	4.98	12.25	20.33	20.34
Qatar	0.73	1.92	3.77	5.82	8.46	12.71	18.49	18
KSA	3.07	21.14	39.49	63.52	83.42	120.65	144.23	139.59
UAE	1.13	5.57	16.19	23.04	27.71	44.87	55.98	52.57

CO_2 emissions (million tonnes) by sector in 2016

	Total CO_2 emissions from fuel combustion	Electricity and heat production	Other energy ind. own use	Manufacturing industries and construction	Transport	Residential
Bahrain	29.6	20.1	3.5	2.1	3.6	0.3
Kuwait	90.2	43.5	13.9	17.6	14.2	0.9
Oman	63.1	16.1	7.7	23.8	15.2	0.6
Qatar	79.1	20.6	31.3	13.6	13.2	0.4
KSA	527.2	246.1	28.6	110.8	136.9	4.9
UAE	191.8	85.6	2.6	68.2	34.6	0.8
Total	981.3	432	87.6	236.1	217.7	7.9

CO_2 emissions (million tonnes) 1971- 2016

Total CO_2 emissions from fuel combustion

	1971	1975	1980	1985	1990	1995	2000	2005	2010	2015	2016
Bahrain	2.9	5.2	7.2	9.1	10.7	13.5	15.8	20.6	25.6	30.1	29.6
Kuwait	14	15.1	26.4	36.7	27.8	32.4	46.3	64.8	77	90.6	90.2
Oman	0.3	0.7	2.2	5.6	10.2	14.7	20.4	25.2	42.4	63.6	63.1
Qatar	2.2	4.9	7	10.7	12.4	16.8	21.3	33.2	55.5	77.6	79.1
KSA	12.7	22.5	99.4	117.8	151.1	191.7	234.6	298	419.2	531.6	527.2
UAE	2.5	4.9	19.2	35.6	51.9	69.7	79.9	111.1	154.6	186.6	191.8
CO_2 emissions from Coal											
Bahrain	0	0	0	0	0	0	0	0	0	0	0
Kuwait	0	0	0	0	0	0	0	0	0	0	0
Oman	0	0	0	0	0	0	0	0	0	0	0
Qatar	0	0	0	0	0	0	0	0	0	0	0
KSA	0	0	0	0	0	0	0	0	0	0	0
UAE	0	0	0	0	0	0	0	0.6	2.6	6.8	7.3
CO_2 emissions from Oil											
Bahrain	1.1	1.1	1.5	1.6	2	2.3	2.4	3.5	3.8	4.4	4.4
Kuwait	4.1	5.2	13.2	27	16.2	14.6	27.9	41.2	49.1	50.5	47.5
Oman	0.3	0.7	1.5	3.5	5.2	7.9	8.7	10.4	11.3	18.1	17.2
Qatar	0.3	0.7	1.4	1.6	1.9	2.4	2.8	6.6	12.5	15	16.1
KSA	10	17.1	78.5	89	107.9	137	167.8	196.5	288.3	375.2	365.6
UAE	0.4	1.7	9.5	15.7	18.6	20.9	21	28.3	36.6	39.2	43.1
CO_2 emissions from Gas											
Bahrain	1.8	4.1	5.7	7.5	8.7	11.2	13.4	17.1	21.7	25.7	25.2
Kuwait	10	9.9	13.2	9.7	11.6	17.8	18.4	23.6	27.9	40.1	42.7
Oman			0.7	2.1	4.9	6.8	11.7	14.8	31.1	45.6	46
Qatar	1.9	4.2	5.6	9.1	10.5	14.4	18.5	26.6	43	62.6	62.9
KSA	2.7	5.4	20.9	28.8	43.2	54.7	66.8	101.5	130.9	156.4	161.7
UAE	2.1	3.3	9.7	19.9	33.3	48.8	58.8	82.2	115.4	140.6	141.5

Electricity generation in Gigawatt hours (GWh) 1973- 2016

Total electricity generation (GWh)								
	1973	**1980**	**1990**	**2000**	**2005**	**2010**	**2015**	**2016**
Bahrain	500	1660	7989	13859	19373	23824	28484	28510
Kuwait	3651	9023	18477	32323	43734	57029	68288	70094
Oman	47	818	4501	9111	12663	19819	32758	34210
Qatar	420	2416	4818	9134	14396	28144	41499	42307
KSA	2949	20452	69208	126191	176124	240067	338342	344809
UAE	720	6306	17080	39944	60698	97728	127366	129596
Electricity generation fromnon-hydro renewables and waste								
Bahrain	0	0	0	0	0	0	0	0
Kuwait	0	0	0	0	0	0	0	0
Oman	0	0	0	0	0	0	0	0
Qatar	0	0	0	0	0	0	0	0
KSA	0	0	0	0	0	0	0	0
UAE	0	0	0	0	0	0	292.942	349.909
Electricity generation from coal								
Bahrain	0	0	0	0	0	0	0	0
Kuwait	0	0	0	0	0	0	0	0
Oman	0	0	0	0	0	0	0	0
Qatar	0	0	0	0	0	0	0	0
KSA	0	0	0	0	0	0	0	0
UAE	0	0	0	0	0	0	0	0
Electricity generation from Oil								
Bahrain	0	0	0	0	0	0	8.5452	2.851
Kuwait	355.973	3956.59	10241.8	21675.8	32761.1	37279.9	43554.1	44790.1
Oman	47	176.034	826.834	1564.36	264.657	445.928	861.535	940.775
Qatar	39.984	64.9904	0	0	0	0	0	0
KSA	2949	5798.14	33918.8	68105.3	76631.6	129300	149547	140165
UAE	0	233.953	633.668	1234.27	1298.94	1446.37	1579.34	1606.99
Electricity generation from natural gas								
Bahrain	500	1660	7989	13859	19373	23824	28475.5	28507.1
Kuwait	3304.16	5066.41	8235.2	10647.2	10972.9	19749.1	24733.9	25289.9
Oman	0	641.966	3683.17	7546.64	12398.3	19373.1	31896.5	33269.2
Qatar	380.016	2351.01	4818	9134	14396	28144	41499	42307
KSA	0	14653.9	35289.2	58085.7	99492.4	110767	188795	204644
UAE	720	6072.05	16446.3	38709.7	59399.1	96281.6	125494	127639
Other	1963.87	1980	1981	2000	2005	2010	2015	2030.02

Total primary energy supply (Mtoe)

Total primary energy supply (TPES) (Mtoe)

Total	1973	1980	1990	2000	2005	2010	2015
Bahrain	2.04	2.81	5.23	7.97	10.39	12.7	14.32
Kuwait	7.13	10.46	9.11	18.72	26.28	32.09	33.67
Oman	0.1	1.15	4.22	7.57	9.91	18.72	25.14
Qatar	1.43	3.31	6.53	10.92	16.67	27.65	43.87
KSA	7.23	31.1	58.01	97.87	122.56	185.51	221.71
UAE	1.31	7.23	20.43	31.53	44.51	61	76.94
Coal							
Bahrain	0	0	0	0	0	0	0
Kuwait	0	0	0	0	0	0	0
Oman	0	0	0	0	0	0	0
Qatar	0	0	0	0	0	0	0
KSA	0	0	0	0	0	0	0
UAE	0	0	0	0.15	0.66	1.71	1.84
Oil							
Bahrain	0.69	0.37	0.8	1.12	1.97	2.11	2.15
Kuwait	2.15	4.82	4.18	10.88	16.24	20.23	16.6
Oman	0.1	0.84	1.78	2.18	2.47	3.82	4.06
Qatar	0.14	0.47	0.97	1.45	2.9	4.71	0.41
KSA	5.7	21.95	38.51	67.08	76.59	125.6	150.43
UAE	0.26	3.11	6.25	6.46	9.11	10.94	14.99
Gas							
Bahrain	1.34	2.43	4.43	6.85	8.42	10.57	12.16
Kuwait	4.96	5.63	4.92	7.84	10.05	11.86	17.07
Oman	0	0.31	2.44	5.39	7.44	14.9	21.09
Qatar	1.29	2.85	5.56	9.47	13.77	22.93	43.46
KSA	1.54	9.15	19.49	30.78	45.97	59.9	71.27
UAE	1.05	4.12	14.18	25.05	35.22	49.35	60.13
Renewables							
Bahrain	0	0	0	0	0	0	0
Kuwait	0.02	0	0.01	0	0	0	0
Oman	0	0	0	0	0	0	0
Qatar	0	0	0	0	0	0	0
KSA	0	0	0.01	0	0.01	0.01	0.01
UAE	0	0	0	0.02	0.03	0.05	0.11

Appendix (III): Data for econometric analysis

Bahrain

Years	GDP per capita	EC per capita (kt of oil equivalent)	CO_2 per capita (metric tons)
1990	8529	10555.27	25.1
1991	9055.6	10108.35	23.3
1992	9082.7	10837.73	20.8
1993	9698.1	11142.36	27.3
1994	10130.4	11555.54	26.9
1995	10376.9	11408.52	26.3
1996	10544.7	11109.67	27
1997	10672.2	12181.22	29.1
1998	10076.2	12406.71	30
1999	10401.5	11851.53	28.3
2000	13636.3	11988.72	28.1
2001	12868.2	11738.15	20
2002	13102.3	11548.55	21.4
2003	14222	11566.5	21.1
2004	15846.5	10894.96	21.1
2005	17959.2	11675.41	21.6
2006	19308	11604.25	19.6
2007	20977.1	11234.22	25.9
2008	23067.6	11318.78	26.7
2009	19356.7	10339.6	23.8
2010	20722.1	10207.85	23.6
2011	22512.2	9911.8	22.4
2012	23649.4	9657.57	20.5
2013	24737.2	10416.79	23.8
2014	24983.4	10594	23.4

Kuwait

years	GDP per capita	EC per capita (kt of oil equivalent)	CO_2 per capita (metric tons)
1990	8776.7	4338.51	24.3
1991	5408	1322.23	5
1992	7092.4	2830.4	14.6
1993	6250.2	2076.3	9.8
1994	6671.3	2453.3	12.2
1995	16882.4	9183.85	34
1996	19300.9	8915.14	30.7
1997	17696.1	8566.78	32
1998	14126.9	9142.51	28.2
1999	15391.3	9206.81	27.6
2000	18389.4	9126.91	26.1
2001	16541	9470.09	27.3
2002	17789.4	9582.18	27.2
2003	22071.6	10096.45	27.6
2004	26921.1	10583.84	28.8
2005	35490.3	11544.16	31.4
2006	42717.6	10795.27	31
2007	45794	10491.59	30.1
2008	55572	10825.77	31.2
2009	37567.3	11142.56	31
2010	38497.6	10699.32	29.9
2011	48268.6	10147.53	28.5
2012	51264.1	10953.22	30.1
2013	48399.9	9708.27	27.3
2014	42996.4	8956.82	25.2

Qatar

Years	**GDP per capita**	**EC per capita** (kt of oil equivalent)	**CO_2 per capita** (metric tons)
1990	15448.7	13698.29	24.7
1991	14120.3	14814.29	36.3
1992	15430.7	15239.45	54.1
1993	14268.5	15622	61.3
1994	14542.5	15509.5	59.6
1995	15849.3	15870.84	61.9
1996	17345	16555.07	61.8
1997	21132.9	19031.75	70.1
1998	18631.8	19388.48	58.9
1999	21763.5	19875.21	55.2
2000	29986.3	18438.15	58.6
2001	28430.6	19562.26	67.1
2002	29990.7	21142.15	63.4
2003	34177	20523.32	60.3
2004	41818.4	21959.44	56.6
2005	51488.5	19268.69	58.9
2006	60256.6	19389.47	62.8
2007	67005.6	18607.43	53.2
2008	82967.4	16371.35	46.7
2009	61478.2	15233.92	43.5
2010	70306.2	15531.78	40.7
2011	85948.1	16030.61	41.2
2012	88564.8	18055.61	44.6
2013	88304.9	17926.72	37.8
2014	86852.7	18562.67	45.4

Oman

Years	GDP per capita	EC per capita (kt of oil equivalent)	CO_2 per capita (metric tons)
1990	6448.1	2328.3	6.3
1991	5988.8	3083.72	6.2
1992	6278.6	2751.75	6.1
1993	6029.2	2863.38	6.5
1994	6013.2	2811.08	7.1
1995	6261.7	2767.63	7.2
1996	6830.6	2803.86	6.8
1997	7039.6	2998.06	6.9
1998	6255	3016.58	7.4
1999	6967.1	3122.25	9.2
2000	8601.2	3337.28	9.7
2001	8476.6	3345.71	8.8
2002	8629.1	3458.45	10.9
2003	9069.8	3606.03	13.6
2004	10129.3	3602.62	11.4
2005	12377	3944.38	11.9
2006	14408.1	5973.86	15.3
2007	15805.1	6646.34	16.4
2008	22075	5673.57	15.5
2009	16784.3	5486.31	14.3
2010	19280.7	6154.42	15.6
2011	20986	6800.14	16.7
2012	22134.9	6832.83	17.1
2013	21268.8	6583.46	16.5
2014	20458.5	6141.77	15.4

Saudi Arabia

Years	GDP per capita	EC per capita (kt of oil equivalent)	CO_2 per capita (metric tons)
1990	7204.7	3552.71	11.4
1991	7838.8	4002.95	15.9
1992	7888.2	4426.46	16.4
1993	7445.1	4471.45	17.6
1994	7382.1	4588.95	16.8
1995	7650.7	4510.42	12.6
1996	8293.2	4728.23	13.5
1997	8508.5	4422.54	11.1
1998	7382.2	4623.7	10.4
1999	7968.5	4611.62	11.2
2000	9127	4712.74	14.3
2001	8643.5	4715.13	14
2002	8655.3	5078.5	14.9
2003	9567.5	4990.77	14.5
2004	11138.8	5157.48	17
2005	13739.8	5126.34	16.6
2006	15334.7	5525.02	17.6
2007	16472.2	5556.71	15.4
2008	20037.8	6034.52	16.6
2009	16094.3	6250.33	17.6
2010	19259.6	6763.34	18.9
2011	23770.7	6307.89	17.7
2012	25303.1	6888.07	19.4
2013	24934.4	6417.92	18.1
2014	24575.4	6937.23	19.5

UAE

Years	GDP per capita	EC per capita (kt of oil equivalent)	CO_2 per capita (metric tons)
1990	27256.3	10979.65	28
1991	26168.3	11922.63	28.9
1992	25993.6	10714.33	27.9
1993	25199.3	10652.13	29.9
1994	25467.2	11188.16	31.4
1995	26847.1	11305.33	28.8
1996	28615.6	11368.98	16
1997	29199.5	11435.91	15.4
1998	26663.3	11125.37	28.7
1999	28260	10789.95	26.2
2000	33071.3	9991.42	35.7
2001	31061.5	12087.1	30.5
2002	31311.4	11369.48	24.2
2003	33230.5	10484.09	28.6
2004	36161.2	10238.1	27.7
2005	39439.8	9716.63	25.4
2006	42372.2	8812.97	23.6
2007	42672.6	8295.73	22.4
2008	45758.9	8604.06	22.8
2009	33072.6	7820.25	21.9
2010	35049.1	7458.88	19.4
2011	40462.3	7418.41	19.1
2012	42112.2	7683.88	19.8
2013	43350.6	7766.67	19
2014	44449.7	7769.23	23.3