

An Analysis of Environmental Kuznets Curve in the Gulf Cooperation Council (GCC) from 1995-2020

Abstract

Purpose: The main motive of the present study is to investigate the Environmental Kuznets curve hypothesis (EKC) in six Gulf Cooperation Council (GCC) countries from 1995-2020. To attain this aim the time series model is built by utilizing CO₂ emission as an environment indicator and GDP per capita, energy consumption and urbanization as economic indicators.

Model specification/ Methodology: Phillips Perron's (PP) unit root test is applied to check the maximum order of integration among variables. Auto-regressive distributed lag (ARDL) bounds estimation model is applied to test the existence of co-integration among variables.

Findings: The study found that the EKC hypothesis applies to Saudi Arabia, UAE and Qatar after comparing the long run and short-run income elasticities. The results of the Toda–Yamamoto–Dolado–Lütkepohl (TYDL) non-granger causality test showed unidirectional causality between carbon emissions and energy consumption in Kuwait and Qatar. Bidirectional causality is found between economic growth and energy consumption in the UAE while unidirectional causality is from urbanization to energy consumption in Saudi Arabia, Qatar and Bahrain.

Keywords: EKC, Energy Consumption, Urbanization, ARDL Model, CO₂ Emissions, GCC Region.

INTRODUCTION

Climate change is a great concern in the current scenario. No corner of the globe is immune or resilient to tackle the devastating consequences of climate change. Human activities of all kinds are considered a significant threat to the environment of this planet. These activities contribute directly or indirectly to climate change (Joshua and Bekum). We are at least **one** degree Celsius above preindustrial levels; we are close to what scientists have warned are “unacceptable risks” according to the World Meteorological Organization report (2019). Reducing greenhouse gas emissions, of which CO₂ emissions are a major contributor, is one way to reduce weather and climate extremes-related disasters and improve environmental quality (Shahbaz et al. 2014). Energy consumption in the form of coal, oil and gas plays an important role in the process of growth and development and cannot be overemphasized as it affects every sector of the economy (Nathaniel et al. 2020). This rapid increase in economic growth, energy consumption and urbanization is associated with environmental degradation and has constituted a challenge to the quality of life across the globe. The Paris Climate Agreement, different conventions on biological diversity, combating desertification, sustainable development and other global targets cannot be achieved without systematic and proper management of natural resources. The Gulf Cooperation

Council(GCC)countries of UAE, Saudi Arabia, Kuwait Bahrain, Qatar and Oman are home to 19.8% of the world's natural gas reserves. The region is rapidly expanding as the major contribution to GDP comes from fossil fuel exports, particularly oil and gas. The GCC countries enjoy a greater absolute advantage in natural gas and oil. They alsoenjoy relatively lower prices of fossil fuels due to huge government subsidies for resources. This over-dependence and excessive exploitation of natural resources cause severe threats to the environment in the region such as desertification; water crises and climate change (Qadar et al. 2022). The total Co2 emission from energy consumption for the whole Middle East region was 2117.2 million tones(BP [Statistical](#)Review of World energy2022). Saudi Arabia has been amongst the largest contributors of carbon emissions in the whole GCC region contributing about 575.3Mt in 2021 followed by the U.A.E and Qatar. Furthermore, it appears that Oman is the highest primary energy-consuming countrywith a growth rate of 4.8% from 2011-2021 followed by the Qatar and U.A.E (BP[Statistical](#)report 2022). The factors that contribute to the high demand for energy in the GCC region are urbanization, population growth and rapid economic development. GCC is among the most urbanized regions in the world, changing demography and the surge of migrant workers attracted to the region by employment opportunities anddemonstrated economic success in recent decades have both contributed to these trends. The rapid increase in urban population puts huge pressure on natural resources and affects the urban ecosystem by reducing the carrying capacity (coffin, 2007). Industrial activities in urban areas attract people for better living standards this is closely linked to environmental degradation (Ali et al, 2019). The growth of urban areas increases the pressure on limited resources and is associated with a wide range of urban conditions that pose unprecedented threats to environmental, social, political and economic challenges to policymakers ([Wang](#) et al. 2020). GCCGDP per capita is currentlyamong the highest in the world. As the region's economy has grown, its population has increased significantly over the past few decades and the slit towns have developed into commercial metropolises linked to the global economy ([Sharma](#),et al. 2021).

Conceptual, Empirical and Theoretical review:

The associationbetween economic growth and environmental quality is explained by the environmental Kuznets curve (EKC). This curve advocates an inverted U-shaped association between economic growth and environmental degradation which, hasbeen studiedin recent decades. For example,[Grossman](#) and Kruger made the first analysis of EKC using panel data across Mexico cities and demarcated three effects i.e. level, Composition, technique effects of NAFTA on the environment. ([Panayotou](#),1995),investigated EKC in the Economic Commission of Europe (ECE) and showed transitional economies are on the left side of the inflection point of EKC, while developed economies are on the right side of the inflection point and emphasize policy structure, removal of subsidies and increased investment in education and training.([Destak](#) et al. 2018) found that Mexico,Philippines,Singapore and SouthAfricahave an inverted U-shaped EKC while China, India, South Korea,Thailand and Turkey have a U- Shaped relationship between their ecological footprint

and economic growth. (Youssef, Adel et al. 2020) investigated the EKC hypothesis in 14 MENA countries and verified the bidirectional causality between CO₂ emissions and economic growth. (Shahbaz et al. 2013a) showed that energy consumption and economic growth lead to an increase in CO₂ emissions in the Turkish economy. (Liu et al. 2014) revealed that the EKC hypothesis is valid in Malaysia, both in the short-run and in the long-run. The study found that FDI and trade decline the environmental quality in Malaysia. (Vohra, 2017) finds that the volatile oil prices create a huge risk to the growth stability in GCC economies.

There are huge empirical studies available on EKC in which GDP, the square of GDP and other explanatory variables such as labor, capital (Saboori et al. 2016) energy consumption (Saidi and Rehman (2020), Saqib and Hashmi (2021) FDI (Lau et al. 2014, Ali, Fakhar and Abedi 2017) trade liberalization (Ibrahim 2016, Shahbaz et al. 2012, Kahia et al. 2019). Dar and Asif (2017) with the use of the ARDL framework examined the verification of EKC in India. The study finds the existence of long-run co-integration between financial development, energy consumption and economic growth with CO₂ emission. However, the study did not find any evidence in support of the EKC in the Indian context. Salahuddin et al. (2015) made a panel data analysis of GCC countries from 1980-2012 and showed that bidirectional causality exists between economic development and CO₂ emission while unidirectional causality exists between energy consumption and economic development. Magazzino (2016) explores the relationship between GDP, energy consumption and CO₂ emission in six GCC countries from 1960-2013. The study found that the 'conservation hypothesis' is true for Bahrain, the feedback mechanism is true for Saudi Arabia while the neutrality hypothesis is true only for the U.A.E. Al-Mulali and Ozturk (2015) used the OLS approach to study the cause of CO₂ in MENA countries. They found that trade openness, urbanization, and energy consumption increase CO₂ emissions in the short run while political instability decreases the environmental quality. Some researchers (Bello et al, 2018, Feng et al. 2017, Sebri, 2016) have used ecological footprint, material footprint and carbon footprint as proxies for environmental quality. (Amri and Arouriet al 2019) found that the service sector contribute less to CO₂ emission in MENA countries while energy consumption and financial development have a significantly lower contribution to CO₂ emissions.

The above review of the literature about the EKC hypothesis has produced mixed results. These studies differ due to different model specifications, periods and different proxies for economic growth and the environment. As a result, some studies provide support for the existence of the EKC hypothesis, while others do not find any evidence of the EKC hypothesis for any country or region. The authenticity behind the selection of the GCC region as a case study is that besides, being the world's major oil exporting region, the Arab world is under severe fire of carbon emissions from the large-scale consumption of fossil fuels. The GCC countries like Qatar, Saudi Arabia, and UAE are among the world's major per-capita CO₂ emitters. It is worthwhile to mention that the region has the two-thirds of the world's crude oil reserves and has enormous potential for wind and solar energy. All countries in the region are financially sound, as the oil rents in the economy have ensured sufficient financial liquidity.

Against this background, the main motive of the author is to analyze the Environmental Kuznets Curve hypothesis (EKC) in the case of the GCC countries. Several studies employed panel data for GCC countries to investigate the EKC hypothesis (Saqib et al. 2022, Alkharet al. 2022). This study is based on annual time series data covering the time period from 1995-2020 and may adopt the new pathway of Saboori et al. (2016) to analyze the validity of the EKC hypothesis in GCC countries, which compares the short-run and long-run income elasticity's. Energy consumption and urbanization are used as control variables to reduce the omitted variable bias. These are empirically recognized as the main sources of carbon emissions. The study used carbon dioxide (CO₂) as a proxy variable for environmental degradation. Since the oil discovery in Saudi Arabia during the early 1930's the region remains one of the world's most oil-rich areas. The activities related to oil production, extraction and exploration are responsible for greenhouse gas (GHGs) emissions. Carbon-dioxide (CO₂) accounts for a substantial proportion of GHGs' and is responsible for climate change.

METHODOLOGY

Data Description

The current study investigates the association between Energy Consumption, urbanization, economic growth and CO₂ emissions. The annual data from 1995-2020 is analyzed for all GCC countries namely Qatar, Kuwait, Bahrain, Saudi Arabia, UAE and Oman. The annual time series data of CO₂ emissions measured in metric tons is used as a proxy variable for environmental deterioration while Gross domestic product (GDP) per capita in 2015 US \$ is used as a proxy for economic growth. The GDP per capita is measured in the international currency US \$ which is assumed to mitigate to some extent the exchange rate fluctuations on the data series, Energy Consumption (EC) is taken in kg of oil equivalent per capita, the fossil fuel (oil) combustion is considered the main source of greenhouse gas emissions. Urbanization is taken as a percentage of the total population. Urbanization increases the amount of precipitation, and air pollution and affects the weather patterns of the region/country. The data source for all the variables is from World Development Indicators (WDI).

The relationship between environmental degradation and economic growth can be expressed as a quadratic form of income according to the EKC hypothesis. The general equation of EKC can be expressed as follows

$$E = f(Y, Y^2, Z) \quad (1)$$

Whereas E is an environmental indicator, Y is economic growth and Z is any other independent variable that also affects environmental quality. The problem of co-linearity or multi-co-linearity may arise between GDP and GDP square. To overcome this problem the study first estimates the long-run association between economic growth indicators i.e. (GDP) and environmental indicators (CO₂). In the second step, the study will proceed with the short-run model. In the next step, the coefficients of long-run and short-run GDP are compared. We can conclude that economic growth leads to less

pollution if the long-run coefficient of income is smaller than the short-run income coefficient, i.e. the EKC hypothesis exists. The EKC model we estimate is specified as follows.

$$\ln Co_2 = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln EC_t + \beta_3 \ln URB_t + \varepsilon_t \quad (2)$$

The first step of the analysis is to reduce heteroscedasticity, for this all the variables have been transformed into logarithmic form. In equation (2) $\ln CO_2$ represents the natural log of carbon emissions used as the dependent variable, and $\ln Y_T$ is the natural log of Gross domestic product per capita in constant 2015 US \$. $\ln EC_t$ is the natural log of energy consumption. $\ln URB$ is the natural log of urbanization as a percentage of the population.

Estimation techniques:

The present study is executed to analyze the EKC hypothesis by examining the long-run relationship between carbon emissions, GDP per capita, and urbanization by applying the autoregressive distributed lag (ARDL) co-integration model developed by Pesaran and Shin (2001). The ARDL framework for the equation (2) is as follows:

$$\begin{aligned} \Delta \ln co_{2t} = & \alpha_0 \\ & + \sum_{k=1}^n \alpha_1 k \Delta \ln CO_{2t-k} \\ & + \sum_{k=0}^n \alpha_2 k \Delta \ln Y_{t-k} \\ & + \sum_{k=0}^n \alpha_3 k \Delta \ln EC_{t-k} + \sum_{k=0}^n \alpha_4 k \Delta \ln URB_{t-k} + \gamma_1 \ln CO_{2t-1} + \gamma_2 \ln Y_{t-1} \\ & + \gamma_3 \ln EC_{t-1} + \gamma_4 \ln URB_{t-1} + \varepsilon_t \end{aligned}$$

Whereas α_0 and ε_t are drift component and white noise, Δ is first difference operator α_1 , α_2 , α_3 and α_4 represents error correction dynamics and the terms represented with γ 's indicates long-run association among variables with baseline equation (2). The first step in an Autoregressive distributed lag ARDL bounds model based on ordinary least squares (OLS) is to estimate the equation (2). The joint significance of F-Statistics of the bound is used to test the null hypothesis of no co-integration. $H_0: \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4$ against the alternative hypothesis $H_1: \gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq 0$. The null hypothesis of no co-integration is rejected if the value of F-statistics turns out to be greater than the upper critical value provided by Pesaran et.al (1997). If the value of F-statistics is less than the lower critical value, then we do not reject the null hypothesis that there is no co-integration. However if the value of F-statistics is in between lower and upper critical values then the results are inconclusive.

After long-run relationships among variables have been established, the ECM of Eq. (2) can be formulated as in the following equation.

$$\begin{aligned} \Delta \ln \text{co2}_t &= \alpha_0 \\ &+ \sum_{k=1}^n \alpha_1 k \Delta \ln \text{co2}_{t-k} \\ &+ \sum_{k=1}^n \alpha_2 k \Delta \ln Y_{t-k} \\ &+ \sum_{k=1}^n \alpha_3 k \Delta \ln EC_{t-k} + \sum_{k=1}^n \alpha_4 k \Delta \ln URB_{t-k} + \theta ECM_{t-1} + v_t \end{aligned}$$

Whereas θ is the coefficient of error correction term with a one-year lag, which indicates the speed, at which the variables adjust to the long-run equilibrium. The coefficient of ECT should be negative and statistically significant, which indicates the degree of correction. The study used various diagnostic tests like, normality test, serial correlation test, cumulative sum (CUSUM) and heteroscedasticity test to check the stability of the model.

Toda- Yamamoto-Dolado -Lutkepohl(TYDL) Causality Approach

This study used Toda and Yamamoto (1995) and Dolado and Lutkepohl (1996) (TYDL) causality approach to determine the direction and degree of causality between selected variables. This approach became so well-known among researchers that many scholars have used this method to determine the causality between oil consumption and ecological footprint ([Saboori et al. 2016,](#)) and the causality between economic growth and saving (Oladipo, 2010). This method of causality has certain advantages over other alternatives. For instance, it is suitable in case series is integrated of order (1(0)), (1(1)), (1(2)). This approach is applicable regardless of variables that have long-run co-integration. The TYDL method employs the Modified Wald Statistic to test the significance of parameters of the VAR (k) model, where k represents the suitable lag length for the VAR model. Therefore, the estimation of VAR (k+d_{max}) augments the asymptotic χ^2 distribution of Wald statistic whereas; d_{max} in the model is the maximum order of the integration. **First step**, while estimating the long-run association among variables, it is customary to check the integration order of variables. To carry out this exercise the study used Phillips- Perron's unit root test proposed by Phillips and Perron (1998). The significance of this test is that it can control serial correlation as it is a non-parametric test. **Second step**, the lag length of the variables in the model is selected according to the Akaike Information Criterion (AIC). The **Third step** of the analysis is to conduct the VAR test with its new lag order of (k+d_{max}) finally; the VAR Granger causality test is developed by utilizing the standard Wald Test.

The following hypotheses are tested:

H₀₁: $\phi_{12,1} = \phi_{12,2} = \dots = \phi_{12,k} = 0$, means that economic growth does not Granger cause CO₂ emissions,

H₀₂: $\phi_{21,1} = \phi_{21,2} = \dots = \phi_{21,k} = 0$, means that CO₂ emissions do not Granger cause economic growth.

H₀₃: $\phi_{31,1} = \phi_{31,2} = \dots = \phi_{31,k} = 0$, means that energy consumption does not Granger cause CO₂ emission

H₀₄: $\phi_{41,1} = \phi_{41,2} = \dots = \phi_{41,k} = 0$, means that CO₂ emissions does not granger cause energy consumption
 And so on for all other selected variables.

Table (1): Phillips- Perron unit root test

country	LnCO2	LnY	Ln EC	LnURB	D _{max}
Saudi Arabia	1(1)	1(1)	1(1)	1(0)	1(1)
UAE	1(1)	1(1)	1(1)	1(1)	1(1)
Kuwait	1(1)	1(1)	1(1)	1(0)	1(1)
Qatar	1(1)	1(1)	1(1)	1(0)	1(1)
Bahrain	1(1)	1(1)	1(1)	1(1)	1(1)
Oman	1(1)	1(1)	1(1)	1(1)	1(1)

Note: the optimal lag length is selected automatically by bandwidth using the Newly- West method

Result Analysis and discussions:

The estimation of the ARDL approach of co-integration is used to estimate the long-run association between relevant variables. The co-integration is verified by the joint significance of using F-statistics. It is important to apply different lag-orders of the variables in Eq. (2) in order to find an appropriate lag length. The optimum lag length is selected relying on minimizing the Akaike Information Criterion (AIC) to ensure that assumptions of classical regression are not violated.

Table 2: Results of the ARDL model

	F test	ECM

country	F statistics	coefficient	T statistics
Saudi Arabia	7.71	-0.238	-7.25*
UAE	8.92	-0.768	-7.250*
Kuwait	3.19	-0.567	-4.417*
Qatar	18.17	-0.619	10.59*
Bahrain	7.18	-0.782	-6.851*
Oman	27.72	-0.788	-16.65*

Note : the signs * ,** represents the level of significance at 1% and 5% and the critical values are obtained from Saboori et al.(2016),critical values for the bound test case III: unrestricted, intercept, no trend

In the initial stage of our analysis, the F-test was conducted at optimum lags. The results of the co-integration between variables are shown in Table (2). It shows that the F-Statistic is greater than the upper critical value in all GCC countries i.e. Saudi Arabia, United Arab Emirates, Qatar, Kuwait, Bahrain and Oman. Following the studies of Saboori et al. (2014) Kreamers, Ericson, and Daloda (1992) the Error correcting term (ECT₋₁) is estimated to determine the co-integration. These studies showed that a negative and significant coefficient of Error correction term (ECT₋₁) determines the adjustment of concerned variables towards long-run equilibrium. The results of the ARDL bound test showed that the F-statistic is greater than the upper critical bound in all countries and hence, the co-integration is supported, the coefficients of the error-correcting term are also negative and significant in all countries as shown in the table (2), therefore the long-run relationship between concerned variables is supported. To check the goodness of fit of the model the stability and diagnostic test were also conducted. The diagnostic tests include serial correlation tests by Lagrange multiplier (LM) and Durbin-Watson statistics and regression equation specification error test (RESET) proposed by Ramsey (1969) estimating the square of fitness values. To check the normality of the model Jacque- Berra test based on skewness and kurtosis of residuals is used. The ARCH test was conducted to check the heteroscedasticity of the model that is based on the regression of the square Residuals on square fitted. The CUSUM test and CUSUM square test are used to check the short-run and long-run structural breaks and stability of the model.

The results of the diagnostic test are reported in Table (3). The study accepted the null hypothesis of no heteroskedasticity and no seriality in all selected countries, as there is no serial correlation in all the model residuals and the model has no ARCH effect. The graphical representation of the CUSUM test showed that the parameters are stable, as the plots of the CUSUM test lie between the critical bounds at a five percent level of significance. The coefficients in Eq. (2) are estimated to determine the long-run association among variables. Similarly, to get short-run estimated results the coefficient of variables of Eq. (3) is estimated. To test the applicability of EKC hypothesis in the selected countries the long-run and short-run coefficients of LnGDP are compared. The long-run and

short-run elasticity of income along with long run elasticity of energy consumption and urbanization are reported in Table (4). After comparing the short-run and long-run elasticity of income, it is visible that short-run income elasticity in United Arab emiratus, Saudi Arabia and Qatar are greater and significant at 10% level of significance than long- run elasticity, whereas, the long- run impact of income on co2 emission is negative and insignificant. This proves the existence of the EKC hypothesis in these countries. This inverted U-shaped curve reveals that at higher levels of income environmental quality improved in these three countries. The applicability of the EKC hypothesis in these countries may be the outcome of various efforts and initiatives like **Saudi Arabia’s Vision 2030. UAE’s Vision 2031 and Qatar’s Vision 2030**. The main motive of these initiatives is to achieve green economy and reduce overreliance on hydrocarbons. The estimated results of Table (4) showed that short-run income elasticity in Oman, Bahrain, and Kuwait are smaller than long-run elasticity and statistically significant at 5% and 10% levels of significance respectively. This indicates that there is no applicability of EKC in these countries. Looking at the impact of other variables on Co2 emission the results showed that energy consumption has a positive impact on environmental degradation in Saudi Arabia, UAE, Qatar and Kuwait in the end. The results showed that energy consumption further degrades the environmental quality in these four GCC countries.

Table 3: Results of diagnostic test

country	Serial correlation {P.Value}	Functional form {P.value}	Normality test {P.value}	D.Ws tatisti cs	Heteroscedast icity {p.value}	CUSUM TEST	CUSUM SQ
Saudi Arabia	5.256{0.072}	3.28{0.193}	0.084{0.958}	2.36	1.557{0.45}	S	S
UAE	3.424{0.180}	0.477{0.70}	0.1711{0.917}	2.312	6.144{0.10}	S	S
Kuwait	1.6227{0.65}	1.9304{0.0}	0.2108{0.8999}	2.066	2.9100{0.40}	S	S
Qatar	4.254{0.119}	7.408{0.02}	0.4089{0.8159}	1.959	1.3357{0.51}	S	S
Bahrain	1.297{0.522}	0.080{0.77}	0.7031{0.7035}	1.888	1.087{0.58}	S	S
Oman	1.5027{0.47}	0.347{0.79}	0.248{0.8830}	1.944	1.893{0.59}	S	S

Note: DW stands for Durbin Watson test; S signifies stability of the model.

Authors own calculation

These results are consistent with the findings of Arouri et al.,(2012) and Osman et al. (2016) while in Oman and Bahrain, energy consumption has a negative impact on CO₂ emissions. The coefficient of

energy consumption in UAE is 0.747 and is significant at a 10% level of significance. This large coefficient of energy consumption is evidence that with economic Development demand for energy has been growing at a rapid rate over the past few years therefore the results support the findings of (Alshami et al. 2019). UAE approximately 30% of the country's total energy is used in the desalination of seawater due to the scarcity of freshwater resources

The impact of urbanization in the long-run on CO₂ emission is negative in UAE, Qatar, and Bahrain whereas, in Saudi Arabia, Kuwait and Oman urbanization has a positive and insignificant impact on CO₂ emission. For Kuwait, the share of the urban population remained at 100% (World Bank 2021), this imbalance in urban population has caused serious and complicated health and environmental issues, especially in coastal areas where oil refineries, water desalination stations, and power plants are located (Alshali and Alharbi, 2022). The growth in urban population in the U.A.E, Oman, Qatar and Bahrain is negative and significant; the coefficient ranges from -12.99 in Qatar to -0.326 in the U.A.E, which confirms that the government of the concerned countries is taking positive steps to sustain the environment along with proper and planned urban development. For example, the "Estidama" framework 2008 by the Abu Dhabi Urban Planning Council and other initiatives like green building regulations, and the Pearl Rating System (PRS) all aimed to create a smart and sustainable city. The Initiative by the transport authority is to replace or modify old vehicles to use low sulfur-diesel to cut carbon emissions. The present study supports and is consistent with the work done by (Majumdar et al. 2022) that showed urban population positively impacts the UAE environmental quality due to steps taken by the UAE government towards urban development. For the proper implementation of the TYDL model, the determination of maximum order of the integration of variables is needed. For this Phillips Peron (PP) unit root test was employed. The optimum lag length was selected based on the AIC criterion. The VAR model was conducted in the levels of the data for each country with the lag length $(k + d_{\max})$.

Causality results

Finally, the study proceeds with a non-granger causality test based on the Standard Wald test. The results of the TYDL causality test are shown in table (5). The existence of unidirectional Causality was found between energy consumption and economic growth in the United Arab Emirates, Bahrain and Oman, which supports the "Growth hypothesis" which implies that energy consumption (fossil fuels) is the main determinant of economic growth of these economies. Only bidirectional causality is found in the U.A.E between these two variables. Whereas in most of the GCC Countries (three out of six countries) urbanization granger causes energy consumption. The high level of urbanization in these countries is mainly due to their economically sustainable infrastructure. In the case of Qatar and UAE, emissions appear to mainly cause urbanization implicitly and high growth of carbon emissions may thwart urbanization activities. The results indicate that in two out of six GCC countries (Qatar and Kuwait) there is a unidirectional causal relationship between CO₂ Emission to energy consumption. Lastly, we analyze the relationship between economic growth and energy consumption; the results

showed that it is economic growth that causes energy consumption in the case of UAE, Kuwait and Qatar. While unidirectional causal relationship moving from CO₂ emissions to economic growth in Kuwait implies that high, CO₂ emissions cause a high growth trajectory in Kuwait. It is apparent from the results that energy consumption helps to create an inverted U-shaped EKC curve because it is the main source of government revenue, export earnings and an important determinant of economic growth in GCC Countries. With higher purchasing power, the demand for green technologies and a pollution-free environment increases.

Summary, Conclusion and policy implications

The present study reexamined the hypothesis of the Environmental Kuznets curve (EKC) in the Gulf Cooperation Council (GCC) from the period 1995- 2020. The study utilized CO₂ emissions as an indicator of environmental degradation and GDP growth, energy consumption, and urbanization as explanatory variables. The Auto-regressive-distributed-lag (ARDL) model is applied to study the co-integration among variables. The Toda- Yamamoto-Dolado- Lutkepohl (TYDL) model is applied for Granger causality analysis among variables. For testing EKC hypothesis the study, compare short-run and long-run income elasticities. According to (table 4) Saudi Arabia, UAE and Qatar have inverted U-shaped curves. For these countries, economic growth helps in the adoption of modern and environmentally friendly technologies to bring down the emission levels. Moreover, economic growth represents the major source of environmental damage in Kuwait, Oman and Bahrain, as it has a significant impact on CO₂ emission. The current trend of growing CO₂ emissions and consequent climate issues needed substantial economic and energy policy reforms to sustain economic growth while protecting the environment. Accordingly, the establishment of a higher energy committee is required to increase cooperation among ministers, and regulatory agencies, for the proper implementation of energy conservation policies and codes. To mitigate Extreme weather conditions Saudi Arabia and UAE are leading in the energy transition towards renewable sources in the GCC region. The Saudi Arabia Vision 2030 and Al Dafra plant in UAE is expected to be the world's largest single-site solar power plant and Green Saudi initiative (GSI). In this regard still more emphasis on sustainable energy consumption is required to tackle climate change.

Table 4: Short run and long run coefficients

Country	SHORT RUN		LONG RUN	
	$d\ln Y$	$\ln E$	$\ln Y$	$\ln URB$
Saudi Arabia	0.214(0.015) ***	0.212(0.79)	0.332(0.64)	1.8224(0.896)
UAE	0.2638(0.006) **	0.115(0.420)	0.747(0.009)**	-0.326(0.462)
Kuwait	0.328(0.0197) ***	0.579(0.0001) *	0.084(0.081)	0.484(0.915)

Qatar	0.479(0.0004)	0.204(0.184)	0.549(0.002)*	-12.990(0.000)*
Bahrain	0.667(0.021) ***	1.271(0.016) ***	-0.531(0.236)	-12.852(0.043)**
Oman	-0.7745(0.005) *	7.001(0.0003) *	-1.485(0.009) **	5.605(0.002)*

Note: the numbers in the parentheses are P values. *, **, *** represents the level of significance at 1%,5%and 10% respectively.

The present research revisited the EKC hypothesis in the GCC region by unfolding the nexus between CO₂ emissions, economic growth, energy consumption, and urbanization using a reliable econometric approach. Thus, for further research on this question, the researchers can consider a new set of variables (renewable energy consumption, international trade, human capital formation, social indicators, and geographical factors etc.) for the EKC hypothesis analysis. Energy consumption (fossil fuels) also declines the environmental quality and therefore, countries need to diversify their income sources and shift their energy resources by investing in renewable energy

Figure 1: Graphical Representation of Environmental Kuznets Curve

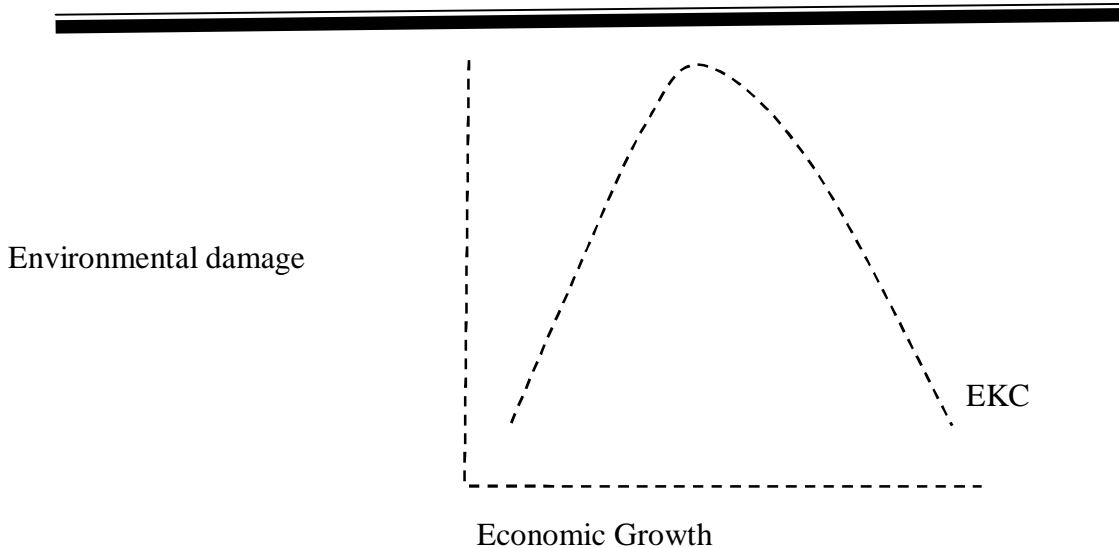
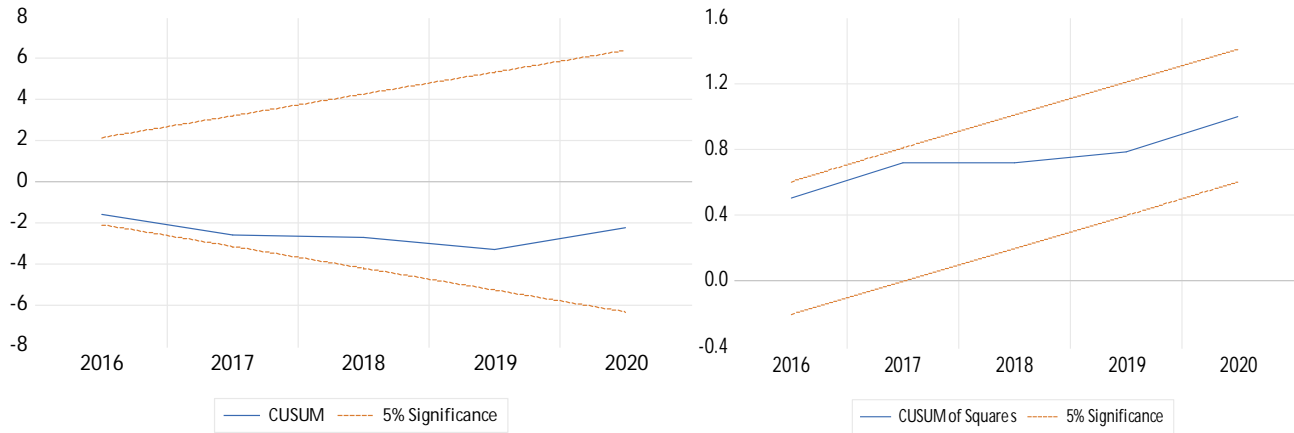


Figure 2: The Plot of Parameter Stability



The impact of urbanization has also found to degrade the environmental quality in Saudi Arabia, Kuwait and Oman. Therefore, the policy implication is that the local government has a proactive role in formulating a holistic approach towards urban development. These countries should impose a carbon tax on energy-intensive urban activities to discourage pollution emissions. Furthermore, to ensure a sustainable future, it is recommended that decision-makers in GCC nations regulate urban patterns in such a manner that is proportional to their existing consequences.

Table 5: TYDL granger causality test results

Saudi Arabia	LnCO2	lnY	lnEC	lnURB
lnCO2	-	4.579(0.101)	0.767(0.6813)	0.061(0.969)
lnY	5.6211(0.06)	-	1.721(0.4229)	0.818(0.664)
lnEC	22.168(0.00)*	2.7355(0.254)	-	1.716(0.423)
lnURB	10.272(0.005)**	1.729(0.421)	10.66(0.004)**	-
UAE				
lnCO2	-	3.2812(0.193)	1.349(0.509)	14.96(0.0006)**
lnY	3.372(0.185)	-	7.100(0.028)	2.702(0.258)
lnEC	1.9704(0.373)	9.007(0.011)***	-	11.199(0.003)
lnURB	0.414(0.812)	11.606(0.003)***	0.311(0.855)	-
Kuwait				
LnCO2	-	7.686(0.021)**	30.91(0.000)*	0.5587(0.756)
lnY	0.109(0.946)	-	12.013(0.002)	0.933(0.627)
lnEC	0.034(0.982)	5.603(0.060)	-	14.058(0.0009)**
lnURB	0.337(0.844)	3.659(0.145)	4.595(0.1005)	-
Qatar				
LnCO2	-	0.943(0.624)	6.970(0.030)***	15.266(0.005)*
lnY	4.248(0.119)	-	16.756(0.0002)**	2.635(0.267)
lnEC	0.075(0.963)	1.800(0.406)	-	5.053(0.070)
lnURB	3.031(0.219)	2.055(0.357)	11.65(0.002)**	-
Bahrain				

Lnco2	-	4.943(0.624)	1.000(0.606)	1.379(0.501)
lnY	5.540(0.062)	-	1.3997(0.496)	0.652(0.721)
lnEC	4.47(0.106)	21.544(0.000)	-	1.783(0.410)
lnURB	10.11(0.006)*	29.70(0.000)	10.76(0.004)	-
Oman				
Lnco2	-	5.565(0.061)	5.286(0.071)	4.110(0.128)
lnY	4.825(0.089)	-	4.214(0.121)	4.704(0.095)
lnEC	2.379(0.304)	14.18(0.008)	-	4.271(0.118)
lnURB	4.096(0.129)	1.425(0.490)	3.141(0.207)	-

The numbers in brackets indicated p. values and signs *, **, *** shows the level of significance at 1%, 5% and 10 % respectively.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that **NO** generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

- 1.
- 2.
- 3.

References

1. AlKhars, M. A., Alwahaishi, S., Fallatah, M. R., & Kayal, A. (2022). A literature review of the Environmental Kuznets Curve in GCC for 2010–2020. *Environmental and Sustainability Indicators*, 14, 100181. <https://doi.org/10.1016/j.indic.2022.100181>
2. Arshad Ansari, M., Haider, S., & Khan, N. (2020). Environmental Kuznets curve revisited: An analysis using ecological and material footprint. *Ecological Indicators*, 115, 106416. <https://doi.org/10.1016/j.ecolind.2020.106416>

3. Asif, M., Sharma, R. B., & Adow, A. H. E. (2015). An Empirical Investigation of the Relationship between Economic Growth, Urbanization, Energy Consumption, and CO₂ Emission in GCC Countries: A Panel Data Analysis. *Asian Social Science*, 11(21). <https://doi.org/10.5539/ass.v11n21p270>
4. Aung, T. S., Saboori, B., & Rasoulinezhad, E. (2017). Economic growth and environmental pollution in Myanmar: an analysis of environmental Kuznets curve. *Environmental Science and Pollution Research*, 24(25), 20487–20501. <https://doi.org/10.1007/s11356-017-9567-3>
5. Baloch, Q. B., Shah, S. N., Iqbal, N., Sheeraz, M., Asadullah, M., Mahar, S., & Khan, A. U. (2022). Impact of tourism development upon environmental sustainability: a suggested framework for sustainable ecotourism. *Environmental Science and Pollution Research*, 30(3), 5917–5930. <https://doi.org/10.1007/s11356-022-22496-w>
6. Ben Lahouel, B., Bruna, M. G., & Ben Zaiied, Y. (2020). The curvilinear relationship between environmental performance and financial performance: An investigation of listed French firms using panel smooth transition model. *Finance Research Letters*, 35, 101455. <https://doi.org/10.1016/j.frl.2020.101455>
7. Destek, M. A., Ulucak, R., & Dogan, E. (2018). Analyzing the environmental Kuznets curve for the EU countries: the role of ecological footprint. *Environmental Science and Pollution Research*, 25(29), 29387–29396. <https://doi.org/10.1007/s11356-018-2911-4>
8. Dkhili, H. (2019). Environmental Performance and Economic Growth in Middle East and North Africa Countries. *Journal of Health and Pollution*, 9(24). <https://doi.org/10.5696/2156-9614-9.24.191208>
9. Esan, B., & Hassan, A. (2020). Nexus between Carbon Dioxide Emission, Energy Consumption and Economic Growth in Nigeria. *International Journal of Sustainable Energy and Environmental*
10. Galeotti, M. (2006). Economic Growth and the Quality of the environment: Taking Stock. *Environment, Development and Sustainability*, 9(4), 427–454. <https://doi.org/10.1007/s10668-006-9030-y>
11. Jiang, Y., & Khan, H. (2022). The relationship between renewable energy consumption, technological innovations, and carbon dioxide emission: evidence from two-step system GMM. *Environmental Science and Pollution Research*, 30(2), 4187–4202. <https://doi.org/10.1007/s11356-022-22391-4>
12. Joo, K., Suh, J. H., Lee, D., & Ahn, K. (2020). Impact of the global financial crisis on the crude oil market. *Energy Strategy Reviews*, 30, 100516. <https://doi.org/10.1016/j.esr.2020.10051>
13. Liobikienė, G., & Butkus, M. (2019). Scale, composition, and technique effects through which the economic growth, foreign direct investment, urbanization, and trade affect greenhouse gas emissions. *Renewable Energy*, 132, 1310–1322. <https://doi.org/10.1016/j.renene.2018.09.032>
14. Meadows, D. H., Meadows, D. L., & Randers, J. (2004). *Limits to growth the 30-year update*. Earthscan.

15. Nathaniel, S., Anyanwu, O., & Shah, M. (2020, February 11). Renewable energy, urbanization, and ecological footprint in the Middle East and North Africa region. *Environmental Science and Pollution Research*, 27(13), 14601–14613. <https://doi.org/10.1007/s11356-020-08017-7>
16. Neagu, O., Ardelean, D. I., & Lazăr, V. (2017). How is environmental performance associated with economic growth? A world cross-country analysis. *Studia Universitatis „Vasile Goldis” Arad – Economics Series*, 27(3), 15–32. <https://doi.org/10.1515/sues-2017-0010>
17. Özcan, B., & Öztürk, I. (2019). *Environmental Kuznets Curve (EKC)*. Academic Press
18. Rasool, H., Malik, M. A., & Tarique, M. (2020). The curvilinear relationship between environmental pollution and economic growth. *International Journal of Energy Sector Management*, 14(5), 891–910. <https://doi.org/10.1108/ijesm-04-2019-001>
19. Saboori, B., Al-mulali, U., Bin Baba, M., & Mohammed, A. H. (2014). Oil-Induced environmental Kuznets curve in organization of petroleum exporting countries (OPEC). *International Journal of Green Energy*, 13(4), 408–416. <https://doi.org/10.1080/15435075.2014.961468>
20. Saidi, K., & Rahman, M. M. (2020). The link between environmental quality, economic growth, and energy use: new evidence from five OPEC countries. *Environment Systems and Decisions*, 41(1), 3–20. <https://doi.org/10.1007/s10669-020-09762-3>
21. Sajeev, A., & Kaur, S. (2020). Environmental sustainability, trade and economic growth in India: implications for public policy. *International Trade, Politics and Development*, 4(2), 141–160. <https://doi.org/10.1108/itpd-09-2020-0079>
22. Saqib, N., Duran, I. A., & Hashmi, N. (2022). Impact of Financial Deepening, Energy Consumption and Total Natural Resource Rent on CO2 Emission in the GCC Countries: Evidence from Advanced Panel Data Simulation. *International Journal of Energy Economics and Policy*, 12(2), 400–409. <https://doi.org/10.32479/ijeep.12907>
23. Sharma, G. D., Shah, M. I., Shahzad, U., Jain, M., & Chopra, R. (2021). Exploring the nexus between agriculture and greenhouse gas emissions in BIMSTEC region: The role of renewable energy and human capital as moderators. *Journal of Environmental Management*, 297, 113316. <https://doi.org/10.1016/j.jenvman.2021.113316>
24. Shafik, N., & Bandyopadhyay, S. (1992). *Economic Growth and Environmental Quality*. World Bank Publications
25. Shahbaz, M., Sbia, R., Hamdi, H., & Ozturk, I. (2014). Economic growth, electricity consumption, urbanization and environmental degradation relationship in United Arab Emirates. *Ecological Indicators*, 45, 622–631. <https://doi.org/10.1016/j.ecolind.2014.05.022>
26. Sheikheinnoddin, A., Tarazkar, M. H., Behjat, A., Al-Mulali, U., & Ozturk, I. (2022, January). The nexus between environmental performance and economic growth: New evidence from the Middle East and North Africa region. *Journal of Cleaner Production*, 331, 129892. <https://doi.org/10.1016/j.jclepro.2021.129892>

27. Torrent-Sellens, J., Ficapal-Cusí, P., & Enache-Zegheru, M. (2022). Boosting environmental management: The mediating role of Industry 4.0 between environmental assets and economic and social firm performance. *Business Strategy and the Environment*, 32(1), 753–768. <https://doi.org/10.1002/bse.3173>
28. Vijayalaxmi, D. K., & Saravanakumar, v. (2017). Economic growth and environmental degradation at Indian context: Environmental Kuznets Curve (EKC) approach. *Asian Journal OF environmental Science*, 12(1), 57–59. <https://doi.org/10.15740/has/ajes/12.1/57-59>
29. Wang, Z., Zaman, S., Zaman, Q. U., & Rasool, S. F. (2021). Impact of remittances on carbon emission: fresh evidence from a panel of five remittance-receiving countries. *Environmental Science and Pollution Research*, 28(37), 52418–52430. <https://doi.org/10.1007/s11356-021-14412-5>
30. Wiedmann, T. O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J., & Kanemoto, K. (2013). The material footprint of nations. *Proceedings of the National Academy of Sciences*, 112(20), 6271–6276. <https://doi.org/10.1073/pnas.1220362110>
31. World bank(2015), world development indicators, Washington