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RESEARCH ARTICLE

Does democracy improve environmental quality of GCC region? Analysis robust to cross-section dependence and slope heterogeneity

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Abstract

Since the developed world's economic prosperity has been heavily reliant on excessive fossil-based energy consumption, it has posed severe environmental quality challenges. This research attempts to revisit the relationship between income and anthropogenic emissions in the context of the environmental Kuznets curve (EKC) theory by considering electric power consumption, urbanization, and democratic accountability index in the Gulf Cooperation Council (GCC) region. It employs annual frequency panel data from 1990 through 2019 and three alternative advanced econometric estimation techniques. The main findings are as follows: *Firstly*, the EKC results for the whole sample strongly support the proposition of an inverse U-shaped connection between anthropogenic emissions and affluence in the long run. *Secondly*, the country-specific results confirm EKC only in Saudi Arabia and Bahrain, while the remaining countries demonstrate a U-shaped connection. *Thirdly*, the democratic accountability promoted anthropogenic emissions implying that it failed to contribute to environmental protection. It means that democratic setup in the GCC region performs poorly in accomplishing climate change mitigation and Sustainable Development Goals (SDGs). *Fourthly*, electric power consumption and urbanization impart positive and negative impacts on anthropogenic emission, respectively. These findings are found robust across the fully modified ordinary least square (FMOLS), bias-corrected LSDV (least squares dummy variable) (LSDV), and pooled mean group (PMG) estimators. *Finally*, Dumitrescu-Hurlin panel causality shows that (i) income and urbanization establish a two-way causality with the anthropogenic emissions. (ii) However, a unidirectional causal connection is revealed from electric power consumption and democratic accountability index to anthropogenic emissions. The findings suggest that the GCC region should prioritize environmental protection and SDGs across the political aims' recipe since it would direct the region on the path of climate change mitigation.

Keywords Democratic accountability index · Environmental Kuznets curve · Electric power consumption · Urbanization · Sustainable Development Goals · Gulf Cooperation Council

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Introduction

Since the last several decades, a plethora of research has given increasing attention to the association between anthropogenic emissions and income. This is especially because developing countries make aggressive efforts towards accelerating economic growth at the cost of skyrocketing levels of anthropogenic emissions. It induced the degradational environmental changes and climatic disturbances worldwide (Dogan et al. 2020; Rahman et al. 2020; Bekun et al. 2020). In light of this situation, the empirical examination of the income-environmental degradation nexus gained massive attention during the era of the 1990s. For instance, Grossman and Krueger (1991) suggested the two stages of income-environmental degradation nexus. In the first stage, affluence increases, and it is connected with the increase in

anthropogenic emission. The second stage suggests that after affluence reaches a certain level, anthropogenic emissions start to decrease. The output of this and similar studies formulated the so-called environmental Kuznets curve (EKC) theory. It proposes the inverted U-shaped relationship between income and environmental degradation. However, there are several studies that observed the N-shaped EKC implying that pollutant emissions started to rise beyond a certain income level (Friedl and Getzner 2003; Bhattarai et al. 2009; Allard et al. 2017; Terrell 2020)

EKC expresses a nonlinear connection between affluence and anthropogenic emissions. As indicated above, in the first stage, economic growth deteriorates the environment. In comparison, the second stage generates circumstances for an economy to safeguard the environmental interests seriously. The increased scale of economic activity, therefore, can be considered a source as well as a cure to the climate change. The argumentation of the EKC theory can be determined on the demand and supply side. The demand side effect declares that the major characteristic of the early phase of the growth process is the worry about the improvement of economic well-being. Economies care less about the environmental protection. However, in the latter phases, the desire for a cleaner environment increases together with the rise in income. Consequently, institutions are more dedicated to developing policies that will regulate the pollution and protect the environment.

On the supply side, the environmental impacts of income are grouped into scale, composition, and technique impacts. The scale effect suggests that the increase in economic activity utilizes incremental resources leading to a more anthropogenic emissions, whereas the composition effect points out the transition of an economy. It actually means the shift in industrial layout from agriculture to secondary industries and, then, to the service sector. Environmental protection actually occurs in the second stage of the composition effect, while the first stage reallocates resources along with the anthropogenic emission. In the last stage, cleaner technologies are introduced to substitute the outdated machinery. The technique effect has a particular objective to provide the up-to-date technology that will help the climate change mitigation. In this regard, the inverse U-shaped association between affluence and environmental depletion is actually the cause of the demand and supply effects.

Although the EKC theory has been investigated empirically and inspected critically while using different samples of interest, this literature has not yet come to an agreement about its existence. Some studies claim its overall existence (Sulemana et al. 2017; Clark et al. 2019; Germani et al. 2020), whereas others (Destek et al. 2018; Effiong and Iriabije 2018) provide completely opposite evidence. The recent literature considered the debate on the shape of EKC as well as the turning point. Furthermore, the inclusion of different variables in the function of the anthropogenic emissions may provide diverse outcomes. This is because income is not the only determinant of environmental quality, but several other factors could contribute to it. Accordingly, there is a need to conduct further studies to shed more light on this association.

In connection with the above, various studies to date also include other variables such as trade openness, energy use, energy prices, financial development, and urbanization to quantify their influence on environmental emissions (Joshi and Beck 2018; Satrovic 2019;Clark et al. 2019; Le et al. 2020; Raza et al. 2020). The present research incorporates urbanization and democratic accountability index since the GCC region has been among the world's regions experiencing a rapid urbanization process (El-Arifi 1986). The Brundtland report about sustainable development was released in 1987, and since then, urbanization is considered at the core of global threats to climate change. The urban population reached almost 55% of the total and is expected to grow by 2.5 billion in 2052 (United Nations 2015). Urbanization incurs huge cost since megacities consume massive energy, emit greenhouse gases, and represent a major unsustainability element, with no exception in the GCC cities. As a consequence, average temperatures increase as well as do the sea level. For instance, Kuwait, in 2016, was deemed the hottest on record in Asia. Urban growth in the Gulf region relied significantly on the cheap fossil fuel-based energy (Al-mulali and Lee 2013). These patterns, however, are far from sustainable practices. Gulf cities have not been active in the international arenas supporting the environmental protection. Despite this, the last 10 years recorded their significant commitment to sustainable practices (Tsai and Mezher 2020).

Climate change has been one of the greatest threats in the Gulf region, making it interesting to research the region. The rising sea level has the potential to completely destroy islands in the region. For instance, Bahrain will potentially lose around 15 km of coastline, and the marine life will be severely affected (Raouf 2008). Governmental policies are of critical importance to face the environmental challenges. However, Gulf political systems are closed and based on the hereditary rule. The only federal state among GCC countries is the United Arab Emirates, whereas the other countries are unitary systems, with the exception of Kuwait (Al-Alkim 1996). As a consequence, royal families have great power and freedom in the decision-making process because of the absence of accountability. It is worth mentioning that GCC governments claim a strong commitment to sustainable development in the recent decades (Tsai 2018). Hence, many projects supporting the sustainable urban agendas are presented. Also, the strategies that will support energy efficiency are adopted by Gulf governments. In the recent decades, Gulf economies' significant effort towards environmental protection motivated the conduction of present research.

The debate directs that the association between environmental depletion and income has not been isolated from governmental policies' influences. Hence, a few new studies have sought to explore an alternative hypothesis that the democratic accountability index can significantly influence the environmental degradation. It is surprising that even though the Cooperation Council for the Arab States face a multitude of "traditional" environmental challenges, not many studies analyze the role of democracy in environmental degradation for these countries. The fact that democracy enables citizens to freely choose environmental policies by the voting mechanism motivated us to conduct this study considering GCC economies. An additional motivation to capture the GCC countries is the reality that there is a lack of knowledge about how democracy and the environment interact. Environmental quality is made up of public goods. For this reason, the democratic accountability index is considered to be an important determinant of environmental quality. Considering that public goods are not in general purchased on the market, the government is expected to coordinate actions towards the environmental protection (Ardiwijaya et al. 2015). These actions can be conducted starting from the local to the national level. For instance, the industrial sector might contribute to greenhouse gas emission reduction due to laws at the national, regional, or local regulations. In fact, the association between the democratic accountability index and anthropogenic emissions is very complex. In the autocratic system, there is a unilateral decision-making system. However, in democracies, a greater voice in the political decision-making process will be given to those concerned with the environment (Tsai 2018). A democratic system, even though it is an autocratic in nature, is very important for the allocation of resources from the environment. If the rule of law does not work well, rent-seeking behavior among officials can be boosted by corruption. Democracy is the only system that has the potential to protect all basic human rights, including clean air and the environment (Gill et al. 2019). Despite the fact that an enormous body of literature has studied the connection between environmental depletion and democracy, the evidence is conflicting. Hence, it is hard to conclude that there is a robust connection between democracy and anthropogenic emission.

The prime objective of this study is to analyze the existence of EKC theory in the GCC region by considering various determinants of pollutant emissions. In this context, the studied panel comprises countries, including Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates. The period ranged from 1990 through 2019. The key contributions of this study are as follows: (1) Considering the limited evidence on the institutional determinants of pollutant emissions and the lack of knowledge about the democracy-environment nexus, this study attempts to fill in this gap in literature by analyzing the validity of EKC theory by considering the role of democracy in GCC countries. (2) The specified model also incorporates urbanization and electric power consumption to estimate more comprehensively their impacts on anthropogenic emissions. (3) The Westerlund's panel cointegration test is employed to investigate a long-term stability path among the variables of interest and to address the cross-sectional dependence. (4) To avoid inconsistent findings and to contribute to filling the existing research gap, three state-of-art panel techniques, including fully modified ordinary least squares (FMOLS), bias-corrected LSDV (least squares dummy variable), and pooled mean group (PMG), are employed for the long-run parameter estimates. (5) The Dumitrescu and Hurlin causality investigates the short-run causal directions. This work's empirical analysis provides useful policy suggestions.

The rest of the research is structured as follows: The "Literature review" section surveys the most updated studies on the EKC theory's presence around the globe. The "Materials and methods" section states the variables and specified model. Additionally, it describes the pre-estimation and estimation methods. The "Empirical results and discussions" section is based on the research findings, along with discussions in the broad spectrum. Finally, the "Conclusion and policy proposals" section is composed of concluding remarks and proposed policy recommendations.

Literature review

Most recently, the role of the type of political system (ranging from autocracy to democracy) in the curtailment of environmental emissions has become an area of interest by researchers and environmental economists worldwide. In this regard, Wang et al. (2018) studied the effects of capitalism, political modernization, and industrialization in the G-20 countries on $PM_{2.5}$ concentrations. Their findings showed that the direct influence of capitalism on concentrations of $PM_{2.5}$ was strongly positive in states with more emissions. In contrast, no effects were observed in states with fewer emissions. The indirect influence of democracy and political dynamics on $PM_{2.5}$ concentrations was studied across the stages of emissions. Both had a negative (positive) indirect influence on $PM_{2.5}$ concentrations in states with less (more) pollution. Next, Germani et al. (2020) empirically analyzed the environmental crime Kuznets curve for 110 Italian provinces between 2010 and 2015. They tracked the democratic, legal, and socio-economic heterogeneity. An inverse U-shaped link was apparent between the variables of their interest. Bjørnskov (2018) evaluated the connection of political and economic freedom with the environmental success. The influence of economic independence and democracy on four climate regulations was quantified in 27 formerly Communist states. It was observed that liberalizing the public sector was correlated with less harm to the environment, merely in the autocratic regimes.

However, Allard et al. (2017) validated the N-shaped EKC for 74 countries in the period of 1994–2012. The findings display negative impact of renewable energy on pollutant emissions. These results are strongly justified by Terrell (2020). The N-shaped EKC is also displayed for Austria in the period of 1960–1999 (Friedl and Getzner 2003) and for 15 Latin America countries in the time-span ranging from 1980 to 2000 (Bhattarai et al. 2009).

Moreover, Obydenkova and Salahodjaev (2017) examined the effect of society's cognitive capital on environmental policy in legislative choices. Based on a broad review of 94 nations, both the political systems and social capital played an integral part in the ruling judgment on climate change policy. The results further indicated that higher social cognitive capital dramatically enhanced the state's willingness to implement environmental policies in a democratic state. After that, Sulemana et al. (2017) estimated the EKC theory for carbon discharge and particulate matter (PM_{10}) in highly developed OECD[1] and African nations. They concluded that, for African and OECD nations, the EKC theory was existent for both carbon dioxide (CO_2) and particulate matter (PM_{10}). Also, the institutional consistency showed an insignificant influence on CO_2 for the two samples. For African nations, a democratic setup was positively associated with PM_{10} pollution. After that, Masron and Subramaniam (2018) assessed the direct and indirect effects of corruption on the climatic deterioration in sixty-four developing nations. Their results showed that in states with high corruption, the degree of emissions was persistently high. Consequently, high corruption eliminated the effectiveness of income influence on the protection of the environment. In their work, Clark et al. (2019) investigated the correlation between democracy and coal power utilization. The EKC relationship was confirmed between democracy and coal using a dataset on coal-fired power stations commissioned in 71 countries from 1980 to 2016. They argued that at a low development level, the governments were supposed to be focused on the provision of inexpensive energy to all from the electorate point of view. Therefore, they chose coal power utilization in those countries. However, at a high level of development, a clean atmosphere was prioritized by the governments. Mujtaba and Jena (2021) examined and found significant links among energy consumption, FDI, and economic progress by using nonlinear ARDL method. Abbasi et al. (2020) investigated and found significant impact of urbanization on carbon emissions in Asian countries. In another research, Satrovic et al. (2020) studied and found significant link between gross capital formation and carbon emissions in Turkey and Kuwait.

Besides, Joshi and Beck (2018) estimated the effect of political independence, economic development, population growth, urbanization, and energy utilization on greenhouse gas emissions. They observed no proof of a CO_2-based EKC for the OECD/non-OECD regions. They further showed mixed findings of the effect of political and economic independence depending on the country. Fatima et al. (2019) examined and found significant connection among energy consumption, human capital, and aggregated energy use in Pakistan. In their study, Güngör et al. (2020) analyzed the EKC theory by integrating the energy use and political transparency for Algeria, Sri Lanka, Haiti, Kenya, Turkey, Romania, Zimbabwe, Yemen, and Iran between 1990 and 2018. In the long term, the observational findings validated the EKC theory. Their findings further demonstrated that power usage substantially raised the long-term and short-term CO_2. In contrast, the political oversight significantly decreased the long-term CO_2.

Several studies investigated the EKC theory's existence by incorporating various variables in diversified empirical and theoretical frameworks. In the oil-producing nations, Ike et al. (2020) researched the long-term consequences of oil production on the atmosphere's emissions. For this, they used quantile regression to control distributional heterogeneity in the new Moments Method. They uncovered that the production of petroleum and energy increased CO_2 discharge. On the contrary, trade reduced the pollution. Next, Chen et al. (2020) evaluated the CO_2 emissions at the city scale in China and reviewed the EKC to benchmark policymaking. The EKC was checked using the STIRPAT model based on 291 China cities. Their findings revealed that, at the provincial scale, the coefficient of the determination reached 85% for the estimated CO_2. In China, western cities produced more CO_2 than the eastern cities, economically strong and manufacturing-oriented regions. After that, Brown et al. (2020) considered the linkage between CO_2 and transfer inflows. To this end, they applied the autoregressive distributed lag (ARDL) approach to Jamaica's data from 1976 to 2018. They aimed to clarify the causal connection between the two variables. Their results showed the following key points. Firstly, there was a long-term cointegration linkage between the remittances and CO_2 per capita. Secondly, the asymmetric link was found between the two variables only in the short term.

Furthermore, Le et al. (2020) explored a nonlinear connection between the diversification of exports and income inequality using a large panel of ninety countries from 2002 to 2014. The long-term linkage between export divergence, macroeconomic patterns, and income disparity was found present. Leitão (2010) studied a large panel of countries at varying stages of growth and inequality to analyze the influence of corruption. The corruption was found to influence the income levels at the turning points. The increased corruption in the world boosted the income per capita at the turning point. For 46 sub-Saharan African countries, the effect of capitalism and clean energy on carbon intensity was analyzed, using unbalanced longitudinal data from 1980 to 2015. The analysis

[1] Organization for Economic Co-operation and Development

demonstrated that carbon emissions were limited by the capitalism and clean energies (Adams and Acheampong 2019). In a different research, three kinds of EKCs were empirically tested in 36 emerging and industrialized nations from 1995 to 2013. It was found that manufacturing practices greatly increased the pollution from traffic and mono-nitrogen oxides (NOx) across the nations. Apergis and Payne (2010) set the stage between renewable energy and economic progress in Eurasia. Then, Asumadu-Sarkodie and Yadav (2019) adopted Prais-Winsten and Cochrane-Orcutt regression mechanisms to explore the connection between emissions and the economic growth, in the transformation from dirty to renewable energy in the Indian context. They used a national time series dataset spanning 1990–2017. Their research verified the presence of a U-form link between the variables of interest at a pivotal moment of US$ 1802.

In addition, Bah et al. (2020) empirically evaluated the EKC theory for ten sub-Saharan African nations with middle incomes, from 1971 to 2012. To further validate the EKC theory, chosen middle-income countries were classified into two groups. Their findings affirmed the presence of a long-term linkage between environmental pollution and primary metrics for the two classes. Bulut (2019) investigated the existence of EKC in the USA. It was further analyzed whether green energy use could minimize CO_2 discharge, using monthly data from 2000 to 2018. The results also suggested that green power usage had a detrimental impact on CO_2 discharge. Nevertheless, those impacts were expected to be more substantial for the intensive utilization of green power in the USA. After that, Destek et al. (2018) explored the EKC theory's existence for the European Union by using a wider ecological footprint proxy. They used the second-generation longitudinal data methodologies during 1980–2013. Their findings signposted that the linkage between actual output and the environmental footprint offered a U-shaped connection. Then, Effiong and Iriabije (2018) explored the EKC theory. They used a compact semiparametric longitudinal fixed-effects approach to define the linkage between income and pollution for data of Africa's 49 nations spanning 1990 to 2010. Their results revealed that the income increased (decreased) the CO_2 (PM_{10}) emissions in a non-monotonic fashion. However, there was no evidence of EKC theory's existence.

In a most recent study, Kasimoglu (2018) calculated the Kuznets curve and the EKC for Turkey, Bulgaria, Romania, Azerbaijan, Iran, Gabon, and Mexico. In terms of growth, it was revealed that the developed economies with increasing anthropogenic emissions or inequalities would not be prosperous. Further, Erko (2016) studied the interlinks among clean energy, fossil fuels, economic development, and CO_2 between 1970 and 2013. The multivariate time series techniques were employed. The findings indicated that a long-term connection was present. Moreover, an EKC theory was found in the case of Turkey. The case of Turkey was also explored by Satrovic (2019). Also, Gara (2019) explored young African students' opinions in China on environmental contamination and deterioration through a questionnaire survey. The analysis demonstrated that 72% of the students agreed on EKC existence. The results further showed the development path that the majority of Africans were likely to follow.

Additionally, Gill et al. (2018) researched the EKC presence in the Malaysian context, for GHG emissions over 1970–2011. Their findings showed a high gross domestic product (GDP) level for Malaysia at the EKC turning stage. Consequently, they claimed that the environmental deterioration in Malaysia could not be reversed only through economic development. Next, Liu et al. (2016) simulated the link of industrialized water pollution, chemical oxygen demand, and ammonia with the GDP of Zaozhuang from 2002 through 2012. In this regard, they aimed to identify the presence of EKC based on water quality in Zaozhuang. Their models' outcomes showed an inverse U-shaped connection between the output and the industrialized effluents discharged. Then, Polemis (2018) tested the relevance of EKC theory by reflecting the business system's effect on industrial emissions based on highly toxic effluents. Semiparametric fixed effects regression estimator was used from 1987 through 2012. The association between industrialized manufacturing and dangerous chemicals revealed an inverted "U shape." Finally, for the Next-11 and BRICS nations, Raza et al. (2020) estimated residential energy-based EKC's presence, integrating economic growth, green energy use, and financial growth, spanning 1990 to 2015. Their findings proved that all the factors were co-integrated in the long-term. Besides, residential energy use, economic growth, and financial growth had a substantial and beneficial impact on environmental deterioration.

There are many studies exploring the validity of the EKC hypothesis in the Middle East and North Africa; however, the evidence on GCC countries alone is lacking. For instance, Alsamara et al. (2018) confirm the existence of EKC hypothesis for GCC region in the period of 1980–2017. In addition, Charfeddine and Mrabet (2017) support the validity of EKC hypothesis in oil-exporting countries. In their study, Ben Zaied et al. (2017) support the inverted U-shaped relationship between affluence and pollutant emissions in 12 Middle East and North African countries in the period of 1980–2013. Similarly, Mahmood and Alkhateeb (2017) and Mahmood et al. (2018) confirm the validity of EKC hypothesis for the case of Saudi Arabia. However, the EKC hypothesis does not stand for GCC countries in the period of 2001–2016 as outlined by Maneejuk et al. (2020) pointing out that transition in the pollutant emissions along the EKC phenomenon occurs only among developed economies. More recently, Ansari et al. (2020a) analyze the case study of GCC countries in the period of 1991–2017 and suggest that EKC hypothesis is not

valid using ecological footprint as a proxy for environmental degradation. Similarly, EKC hypothesis does not exist in case of West, South, and Southeast Asian countries in the period of 1991–2017 (Ansari et al. 2020b).

Given the survey of the most recent empirical literature on EKC, it has been extracted that various types of governmental setups played a critical role in the environmental policies. However, their findings presented a mixed picture of the nature of the impacts of those setups. By and large, the democratic setup was found to exploit the environmental condition. It manifested the scenario that the democratic governments' mission is to provide inexpensive access to everyone for the electoral gains. Therefore, they promote cheap energy sources like oil, which escalate the environmental degradation. Contrastingly, the autocratic setups were largely found to mitigate the environmental emissions by enforcing environmental protection policies. However, the above literature debate also exhibited that a democratic setup improved developed nations' environmental sustainability. Because of this argument, this work hypothesizes whether the democratic element in the GCC region improves or deteriorates environmental sustainability. Besides, EKC's existence has been tested by incorporating the democratic accountability index, along with urbanization and electric power consumption as control variables.

Materials and methods

Data and model specification

This study uses a comprehensive dataset over the time span 1990–2019 in the GCC region in a balanced panel framework. Carbon dioxide emissions per capita (metric tons), CO_2PC, was taken as the indicator of anthropogenic emissions. Per capita GDP (constant 2010 US$), PCGDP, assesses real output to proxy the affluence, while the electric power consumption per capita (kWh), EPPC, is used as a proxy for electricity use (Muslija et al. 2020). Additionally, it introduces the squared term of affluence to investigate the EKC existence. Next, it incorporates the urban population (% of the total population), URB, to evaluate the impact of urbanization. To incorporate the democracy, it has used a democratic accountability index (DEM). This index is widely used in political science. DEM can take the values between 0 and 6 where higher index values show a higher level of democracy and vice versa. Table 1 summarizes data source and unit of measurement.

The Cooperation Council for the Arab States of the Gulf known as the Gulf Cooperation Council is a regional union consisting of six Arab states of the Persian Gulf (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates). The institution was formally established in 1981.The Gulf region has changed substantially in the last few decades. Due to the significant oil reserves and oil revenues, GCC has experienced the acceleration development. Moreover, new cities were created where significant funds were directed to support the infrastructure. In addition, this region has attracted labor and capital from all over the world and established new industries. The growth performance of GCC countries has been much higher compared with other developed economies or oil exporters (Hvidt 2011). Since 1986, Gulf countries have more than doubled their economies. Besides this, new industries creating new workplaces attracted many foreign workers. It is also worth mentioning an impressive population growth rate in the Gulf region, decreasing the real output per capita (Maalel and Mahmood 2018). Although this region reports significant progress in terms of macroeconomic indicators and represents key oil exporter, not many studies evaluate the validity of EKC theory.

The GCC region was formed in 1981 with a particular objective to boost their development by strengthening integration. It was formed for Arab Gulf states: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates (in alphabetical order). These countries claimed major economic changes since the 1970s (Hvidt 2011). These transformations resulted from an increasing oil price in the early 1970s (Maalel and Mahmood 2018). Addressing the fact that GCC countries currently hold 30% of the world's total oil reserves, oil revenues were the major source of exceptional development in all spheres of life. Saudi Arabia is the oil reserves leader (15.7%), followed by Kuwait (6%). Also, the rising oil prices laid the

Table 1 Data source and description

Indicator name	Code; measurement unit	Source
CO_2 emissions per capita	CO_2PC; metric tons	World Bank (2020); Our World In Data (2021)
Electric power consumption	EPPC; kWh per capita	World Bank (2020); IEA (2021); World Data (2021)
Per capita GDP	PCGDP; constant 2010 US$	World Bank (2020)
Urban population	URB; % of total population	World Bank (2020)
Democratic accountability index	DEM; 0–6 scale, higher index values show a higher level of democracy and vice versa	The PRS Group (2021)

Source: Computed by the authors

foundations of a modern society in GCC countries with significant funds directed towards the development of infrastructure and overall socio-economic development.

Anthropogenic emission is approximated using CO_2PC (metric tons). The maximum value is reported in Qatar in 1997, whereas the minimum value was displayed for Oman in 1992. Qatar is ranked as the highest CO_2PC emitter globally (Verbič et al. 2021), so the maximum value reported in our sample is not a surprise. There are two main arguments supporting this fact. At first, this Gulf country is the largest producer of LNG (liquefied natural gas) and has a relatively small population density. It is important to indicate that Qatar has made a significant effort to reduce CO_2PC. Its indirect impact is through producing and exporting LNG, which is the cleanest fossil fuel. This fuel is considered a good alternative to reduce anthropogenic emissions and support climate change mitigation, especially in the Euro zone. Besides that, Qatar continues the research and development directed towards the reduction of greenhouse gases. On the other hand, Oman is a country that has one of the best records in environmental conservation and greenhouse gas emission. The government of Oman is characterized as the most rigorously "green" government. However, the major environmental challenges faced by Oman include water scarcity, desertification, and water salinity.

Affluence is approximated using PCGDP. This variable's trend is positive, i.e., economic output increases in the observed countries within the period of interest. Qatar reports maximum average PCGDP, whereas the minimum value is claimed for Oman. Qatar has significantly changed its economy in the last decades. Due to oil booms, GDP has doubled many times. Economic output has increased much faster compared with the population meaning that per capita income closely converged to that of developed economies. Likewise, this country witnessed significant amounts in infrastructure, securing the fundaments of sustainable growth (Al-Jundi and Guellil 2018). Oman, like other GCC countries, experienced increasing but unsteady growth. Nevertheless, the lack of diversification of economic activities and limited oil reserves made it difficult to support intensive public spending.

Electricity use is approximated using EPPC (kWh). The maximum average value is reported for Bahrain's case, whereas the minimum value is reported in the case of Oman. Over the last two decades, energy consumption grew by 5.3% in Bahrain. Power generation is strongly dependent on the natural gas, which is a scarce resource. Electric power consumption per capita places Bahrain in the top five countries in the world; therefore, the maximum value reported in our paper is not a surprise. Also, there are large seasonal variations in electric power consumption. Due to the heavy use of air condition units, electric power consumption increases in summer and reaches its lowest levels in January. The next observed variable is urban to the total population. Gulf region is among the world's most urbanized regions, with an overall average of over 87% of the population living in urban areas. Kuwait and Qatar are almost 100% urbanized, while the minimum values are reported for Oman. Maximum democratic accountability index (4.5) is reported for Bahrain in the period of 2003–2011, whereas minimum values of 0 are reported for Saudi Arabia in the period of 1997–2003 and Bahrain in the period of 1998–2000.

Understanding the connection between anthropogenic emissions, affluence, and urbanization is important for sustainable urban development, especially for countries experiencing high-speed urbanization (Chen et al. 2019). Anthropogenic emissions are directly determined by economic activity and total energy consumption. Urbanization affects either output or energy consumption in a multidimensional way. Urbanization transforms the landscape and has a positive association with the real output increasing the use of energy. However, urbanization can also reduce anthropogenic emissions. As a result of the scale effect, in the production process, urbanization may aggregate the pollution. A positive externality of urbanization can be the rise in human capital desiring a clean environment changing the structure of the energy use (Shen and Saijo 2008). The connection between anthropogenic emission and democracy is a much-debated topic in the literature. Iwińska et al. (2019) claim a positive association between environmental protection and democracy in some literature. However, democracies are also assumed to hardly move from political commitments to anthropogenic emissions reductions.

Furthermore, the model's general specification to be explored in our paper follows the functional form of the EKC equation based on Grossman and Krueger and adapted from Halicioglu (2009), Alsamara et al. (2018), Iqbal et al. (2021), and Usman et al. (2019). The adapted form of the function is given as follows:

$$CO_2PC = F\left(PCGDP, PCGDP^2, EPPC, URB, DEM\right) \quad (1)$$

where the CO_2PC is the carbon dioxide emissions per capita, $PCGDP$ indicates the per capita GDP, $EPPC$ denotes the electric power consumption per capita, URB is the demonstration of urbanization, and DEM stands for the democratic accountability index. Considering that the current work utilizes panel data econometrics techniques, the model to be estimated further is rewritten as:

$$\begin{aligned} L(CO_2PC_{it}) = {} & \alpha_0 + \alpha_1 L(PCGDP_{it}) + \alpha_2 L(PCGDP)^2{}_{it} \\ & + \alpha_3 L(EPPC_{it}) + \alpha_4 L(URB_{it}) \\ & + \alpha_5 DEM_{it} + \varepsilon_{it} \end{aligned} \quad (2)$$

where the intercept is denoted by α_0, L stands for natural logarithm, the rest of the αs ' are the regression coefficients to be interpreted, and ε_{it} is the demonstration of the error term. The evidence on the inverted U-shaped relationship will be

given if α_1 is positive and α_2 is negative. In case, when some of these conditions or both are not satisfied, the EKC theory is not valid.

Pre-estimation methods

Before entering into the primary estimations, pre-estimation econometrics techniques are mandatory. The estimation of Eq. 2 raises various estimation issues that should be taken into consideration. Cross-sectional dependence is a frequent issue in panel data estimators. Most of the studies to date appear to ignore this issue, assuming the independent cross-sections. In order to overcome this issue, the first step in our paper is to test the cross-sectional dependence. We further proceed to test for the unit-root utilizing panel unit root test in the presence of cross-section dependence (CIPS). To explore the presence of long-run relationships, we will use cointegration tests. If the evidence on long-run relationships is given, we will further estimate Eq. 2 using the three panel data estimators PMG (Pesaran et al. 1999), FMOLS (Pedroni 2004), and LSDV (Bruno 2005). These methods were also adopted by previous studies such as Alsamara et al. (2018), Baye et al. (2020), Ahmad et al. (2020), and Khan and Hou (2021).

The assumption of cross-sectional independence, in general, does not hold due to increased integration among countries of unobserved common factors. Estimations that assume cross-sectional independence lose efficiency and provide insignificant results (Alsamara et al. 2018). To examine whether the assumption of cross-sectional dependence holds in our sample, we utilize the test proposed by Breusch and Pagan (1980). In our sample, we have T >N; therefore, Breusch and Pagan (1980) test is considered appropriate. To describe this test, we start with the standard panel data model:

$$y_{it} = \alpha_i + \beta' x_{it} + e_{it}, i = 1, \ldots, N \text{ and } t = 1, \ldots, T \tag{3}$$

where the vector of regressors ($K\,x\,1$) is denoted by x_{it} while β denotes the ($K\,x\,1$) vector of parameters. α_i is individual effect and e_{it} is assumed IID. The hypothesis of interest can be formalized as:

$$H_0 : \rho_{ij} = \rho_{ji} = cor(e_{it}, e_{jt}) = 0 \text{ for } i \neq j \tag{4}$$

versus

$$H_1 : \rho_{ij} = \rho_{ji} \neq 0 \text{ for some } i \neq j.$$

Breusch and Pagan (1980) test is based on LM statistics:

$$CD_{lm} = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \widehat{\rho}_{ij}^{2},$$

where $\widehat{\rho}_{ij}$ is the sample estimate of correlation of the residuals. Explicitly:

$$\widehat{\rho}_{ij} = \widehat{\rho}_{ji} = \frac{\sum_{t=1}^{T} e_{it} e_{jt}}{\left(\sum_{t=1}^{T} e_{it}^2\right)^{1/2} \left(\sum_{t=1}^{T} e_{jt}^2\right)^{1/2}} \tag{5}$$

Empirical findings in our paper suggest the cross-sectional dependence in all variables, so there is a need to introduce second-generation panel data unit root test.

The second-generation test to be utilized in this paper is the cross-sectional Im, Pesaran, and Shin (CIPS) by Pesaran (2003) that has a nonstandard distribution, even with a large N.

Panel cointegration

Addressing the long-run relationship among the variables, we further test for panel cointegration among the observed variables using the Westerlund (2007) panel cointegration test. Westerlund (2007) developed four error-based test statistics to evaluate the cointegration in the presence of cross-sectional dependence.

Estimation methods

Assuming that Westerlund's (2007) panel cointegration test finds the cointegration relationship among the variables, the next step is the utilization of the relevant panel data estimator to assess the long-run relationship. The baseline of the fully modified ordinary least square (FMOLS) can be generalized as (Eq. 6):

$$\widehat{\beta}_{NT} = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \left(x_{it} - \overline{x}_i\right)^2\right)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \left(x_{it} - \overline{x}_i\right)\left(y_{it} - \overline{y}_i\right) \tag{6}$$

where the notation is explained above. The baseline framework is further formalized and gives the general form of FMOLS as follows (Eq. 7):

$$\widehat{\beta}_{FM} = \left(\sum_{i=1}^{N} \widehat{L}_{22i}^{-1} \sum_{t=1}^{T} \left(x_{it} - \overline{x}_i\right)^2\right)^{-1} \sum_{i=1}^{N} \widehat{L}_{11i}^{-1} \widehat{L}_{22i}^{-1} \left(\sum_{t=1}^{T} \left(x_{it} - \overline{x}_i\right) y_{it}^{*} - T\widehat{\delta}_i\right) \tag{7}$$

where $y_{it}^{*} = (y_{it} - \overline{y}_i) - \left(\frac{\widehat{L}_{21i}}{\widehat{L}_{22i}}\right)\Delta x_{it} + \left(\frac{\widehat{L}_{21i} - \widehat{L}_{22i}}{\widehat{L}_{22i}}\right)\beta(x_{it} - \overline{x}_i)$ and $\widehat{\delta}_i \equiv \widehat{\tau}_{21i} + \widehat{\omega}_{21i}^{0} - \left(\frac{\widehat{L}_{21i}}{\widehat{L}_{22i}}\right)\left(\widehat{\tau}_{22i} + \widehat{\omega}_{22i}^{0}\right)$. Following Alsamara et al. (2018), this research has also used the PMG estimator, enabling the estimation of coefficients not only in the long run but also in the short run. Besides, this research utilizes bias-corrected LSDV (least squares dummy variable) estimator proposed by Bruno (2005) to estimate dynamic unbalanced panel data models with a small number of individuals. Investigation in this research proceeds further to the estimation of the causal link between the sampled variables. For this

purpose, we have employed the Dumitrescu and Hurlin (2012) Granger causality test. The test statistic is provided by the following expression:

$$DH_{i,t} = \alpha_i + \sum_{l=1}^{p} \beta_i^m DH_{i,t-l} + \sum_{l=1}^{p} \gamma_i^m T_{i,t-l} \quad (8)$$

where m is the optimum lag order, whereas β_i^m demonstrates the parameters' auto-regression term.

Empirical results and discussions

Pre-estimation results

As a first step, this research records the findings of cross-section dependence (Table 2). All of the variables except for the democratic accountability index were expressed in natural logarithm to ease interpretation. This practice is strongly justified by Tharanga (2018) and Güngör et al. (2020). Since T >N, our paper utilizes the Breusch-Pagan LM cross-section dependence test. According to the results, Breusch-Pagan LM strongly rejects the null hypothesis of absence of cross-sectional dependence in the case of all variables. Since GCC countries are highly integrated, the sample reports cross-sectional dependence. Hereby, a second-generation unit root test (CIPS) that accounts for cross-section dependence has been utilized, and the findings are presented in Table 3. Most of the tests suggest the presence of unit root test in log levels in the case when intercept/intercept and trend are included. However, the first differences suggest the stationary properties of CO_2PC, PCGDP, URB, EPPC, and DEM.

Findings of our paper show that all variables are non-stationary in levels but stationary in their first differences (Table 3).

Panel cointegration results

Based on the results of unit root tests, we further examine the long-run relationships between the observed variables. For this purpose, we apply the Westerlund cointegration test. Our findings in Table 4 show that two out of four tests support the long-run association between the variables.

Main estimations results

After confirming the existence of a long-run connection among the sampled variables, our work further proceeds to estimate this relationship utilizing LSDV, FMOLS, and PMG panel data estimation tools on Eq. 2. In the case of estimation using anthropogenic emission as a dependent variable, all coefficients via the FMOLS method are statistically significant. It is worth mentioning the significant positive coefficient with per capita GDP and the significant negative coefficient with its squared form. Table 5 clearly indicates that the evidence of FMOLS estimation gives the validation of EKC theory for Gulf countries. In other words, FMOLS estimation validates an inverse U-shaped relationship between anthropogenic emission and affluence. Electric power consumption had a significant and positive influence on anthropogenic emissions. This is aligned with the empirical findings of Ahmad et al. (2021). Likewise, Mehmood and Tariq found similar findings in South Asian countries. The positive long-run coefficients with real output per capita and electric power consumption are not surprising considering that increasing oil revenues enabled accelerated development in all spheres in GCC countries as well as the urbanization that increased electrical power demand. The negative coefficient with urbanization shows that although GCC area represents one of the most urbanized in the world, these governments are strongly committed to sustainable development and develop many strategies that support sustainable urban agendas.

Moreover, the positive coefficient with DEM shows that democratic accountability is poorly functioning in addressing environmental challenges. GCC economies are important players in the world since these economies significantly contribute to their gross domestic product. However, the economy needs to be divided into two main sectors (oil and non-oil) in order to give a more prominent overview of the structure of Gulf economies. The non-oil sector is further divided into the public and private service sectors (Abdalla and Abdelbaki 2014). The public services sector includes services commonly delivered by the government, while the private services sector includes storage, financial services (banking and insurance), trade, transportation, hotels, etc.

Table 5 and Fig. 1 further show the empirical evidence of PMG and LSDV estimators. Both estimators show long-run positive impacts of real output per capita on anthropogenic emission. Specifically, a percentage increase in per capita

Table 2 The cross-sectional independence

Test/variables	L(CO_2PC)	L(PCGDP)	L($PCGDP^2$)	L(EPPC)	L(URB)	DEM
Breusch-Pagan LM	86.93***	64.91***	64.95***	195.36***	337.38***	57.74***

Note: L, natural logarithm. Significance levels: * p<10%, ** p<5%, *** p<1%

Source: Computed by the authors

Table 3 Result of the unit root tests

Variables	Test	Level		First difference	
		Intercept	Intercept and trend	Intercept	Intercept and trend
L(CO_2PC)	CIPS	−2.32*	−3.11***	−5.69***	−5.78***
L(PCGDP)	CIPS	−2.05	−1.73	−3.57***	−3.68***
L($PCGDP^2$)	CIPS	−2.06	−1.69	−3.55***	−3.66***
L(EPPC)	CIPS	−1.86	−2.02	−4.14***	−4.12***
L(URB)	CIPS	−0.66	−3.18***	−3.04***	−3.99***
DEM	CIPS	−2.22*	−1.98	−3.52***	−3.76***

Note: Significance levels: * p<10%, ** p<5%, *** p<1%

Source: Computed by the authors

GDP increases the anthropogenic emission by 6.181% (via PMG estimator) and 5.644% (via LSDV estimator), ceteris paribus. Significant negative coefficients with per capita GDP squared confirm the validity of the EKC theory. This result is analogous to Ahmad et al. (2021). They found the EKC theory valid across the developing countries. Likewise, Bese et al. (2020) found evidence of ECK theory in China and Australia.

Moreover, electric power consumption had a positive and significant long-run influence on anthropogenic emission. These findings are consistent with Alsamara et al. (2018). The parameter estimates of urbanization (via PMG and LSDV) confirmed a significant and negative long-run impact of urbanization on anthropogenic emissions. This finding was consistent with Gasimli et al. (2019). The democratic accountability had a positive impact on anthropogenic emission in the case of the Gulf region. This evidence is strongly supported by Akalin and Erdogan (2020). In contrast, Obydenkova and Salahodjaev (2017) revealed that the enhanced social cognitive capital improved the willingness to adopt environmental policies in 94 democratic nations. Moreover, Wang et al. (2018) found a negative (positive) influence of democracy and politics on $PM_{2.5}$ concentrations in the states with less (more) pollution in G-20 nations. Contrastingly, Bjørnskov (2018) found an environmental improvement effect of the autocratic regimes in 27 countries with formerly autocratic setup. Murshed and Dao (2020) found the existence of EKC by incorporating the role of export diversification in South Asia. The finding is also consistent with Kirikkaleli and Adebayo (2021). Furthermore, Incekara and Ogulata (2017) emphasized the energy conservation to attain the EKC in Turkey. Similarly, Dogan and Aslan (2017) found emissions escalation impact of energy utilization in the European Union countries. As a further argument, non-renewable (renewable) energy consumption in the same region was revealed to promote (reduce) those emissions (Dogan and Seker 2016).

Table 5 also presents the outcomes of the stability of long-run relationships. The coefficient with error correction term (ECT_{-1}) is statistically significant and negative, claiming the stability of the long-run relationships among the sampled variables. PMG estimation reports a coefficient with ECT_{-1} of −0.42, indicating the convergence speed towards the long-term stability of 42% annually in the case of disequilibrium. The short-run convergence supports the restoration of long-term stability.

As a further step, the individual cross-section estimates are calculated to identify the EKC existence in each of the GCC economies. Fig. 2 presents the PMG estimation-based EKC-existent/non-existent GCC economies. We find that, in the short run, the EKC theory is validated only for Bahrain and Saudi Arabia. In other words, a U-shaped relationship has been found between anthropogenic emission and real output in the short run for the United Arab Emirates, Kuwait, Oman, and Qatar. It has been argued that the key macroeconomic indicators were specially strengthened in the period 2002–2008 in GCC countries. Foreign reserves and investments report solid performance, while real GDP grows at 8% annually on average. Consequently, PCGDP grew by about 32% annually on average in this period. PCGDP reports wide variations among countries due to the diverse population density. Saudi Arabia is the most populous state among GCC countries and reports an average income of 16,000 USD on average, whereas Qatar reports 36,000 USD surpassing the Euro zone (Saif 2009).

In light of this, there are several common features of GCC countries to be emphasized. Firstly, these countries are highly dependent on oil. Increasing oil revenues enabled accelerated development and transformed the GCC countries to become

Table 4 Westerlund panel cointegration test results

Statistic	Value	P-value
Gt	−4.01	0.000
Ga	−11.07	0.877
Pt	−8.99	0.002
Pa	−9.40	0.713

Source: Computed by the authors

Table 5 Cointegrating relationships

Estimation method/variables	FMOLS Pooled weighted	PMG	LSDV
L(PCGDP)	5.427*** (0.000)	6.181*** (0.000)	5.644** (0.028)
L(PCGDP^2)	−0.287*** (0.000)	−0.239*** (0.000)	−0.272** (0.019)
L(EPPC)	0.934*** (0.000)	0.867*** (0.000)	0.757*** (0.010)
L(URB)	−3.039*** (0.000)	−2.269*** (0.000)	−2.781*** (0.000)
DEM	0.208*** (0.000)	0.142*** (0.000)	0.191*** (0.000)
ECT$_{-1}$	-	−0.418***(0.010)	

Note: P-value in parentheses. Significance levels: * p<10%, ** p<5%, *** p<1%

Source: Computed by the authors

important players in many spheres, e.g., geopolitical, construction, tourism, and industry, to name a few (Sweidan and Alwaked 2016). Secondly, fiscal surplus is significant, and the public sector plays a dominant role. Furthermore, the labor force is young and records accelerated growth. One of the Gulf countries' important features is a high dependency on expatriate labor (Saif 2009). The strength in macroeconomic indicators brought some important benefits. For instance, Gulf economies have experienced greater diversification and better convergence towards world trade patterns. Unlike the greater diversification, GCC countries still face the urgency to address the low productivity, improve the functionality of the public sector institutions, and develop sectors less dependent on oil revenues such as manufacturing and service industries (Tessema 2019).

As indicated above, GCC countries face common issues that need to be addressed. Consequently, a common mark was launched in 2008 with a particular aim to improve the mobility of goods, labor, and capital. However, the agreements were not supported by the institutional arrangements

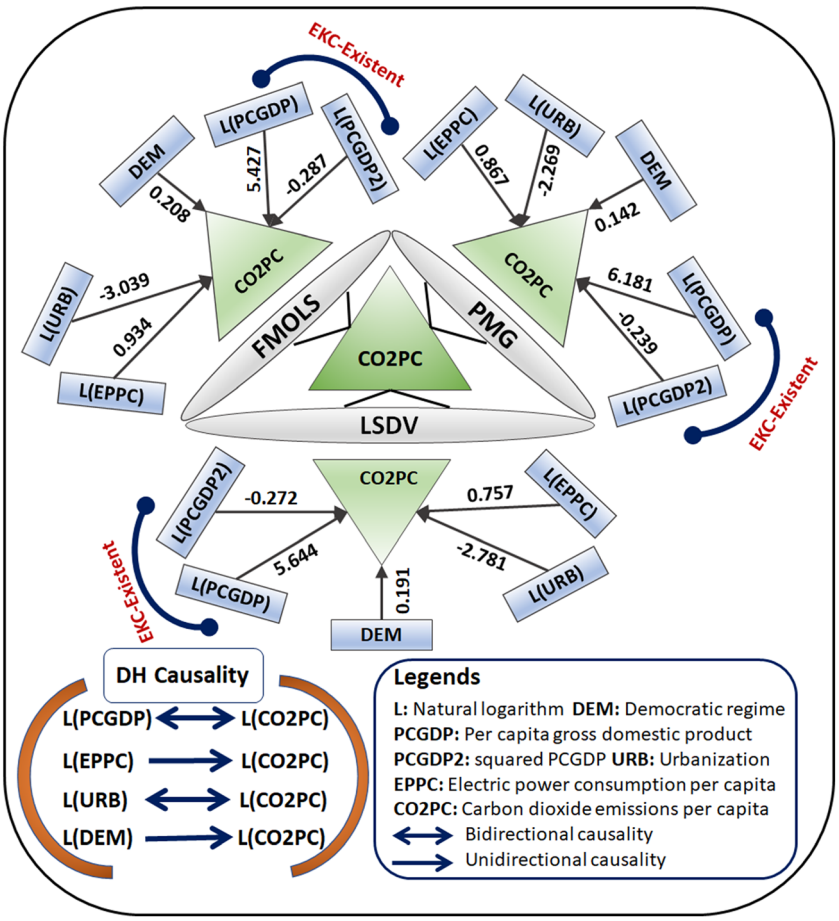

Fig. 1. Long- and short-run outcomes for Gulf Cooperation Council (GCC) economies. Source: Authors' elaboration based on long-run parameter estimates estimated by FMOLS, PMG, and LSDV. Short-run causal findings are based on the DH panel causality approach.

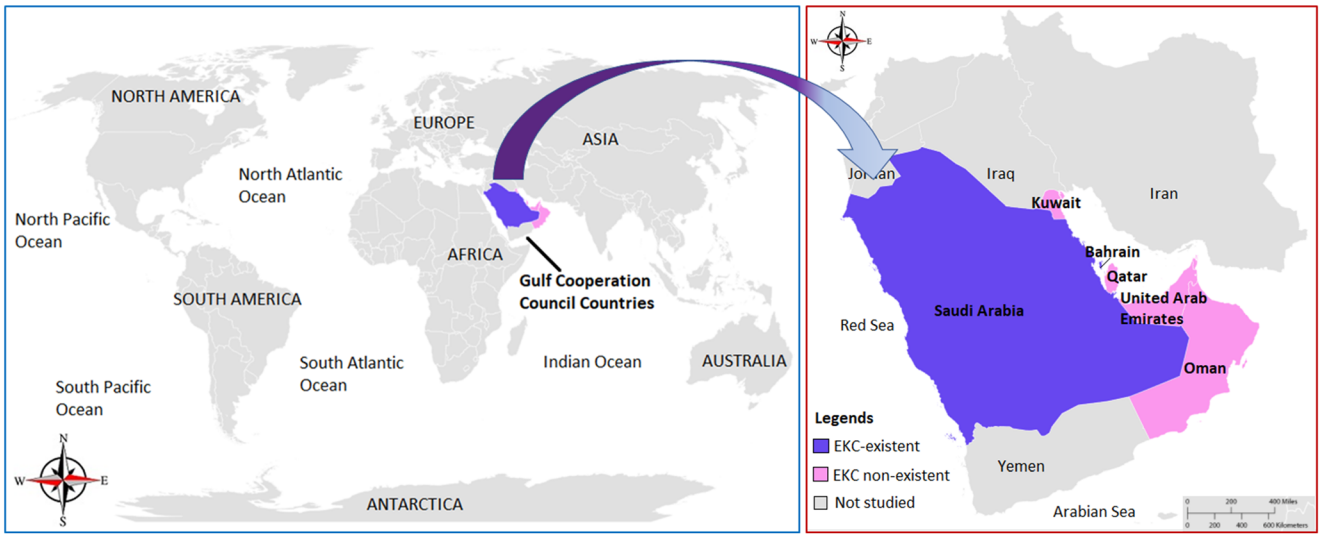

Fig. 2. Location of EKC-existent/non-existent Gulf Cooperation Council (GCC) economies. Source: Authors' elaboration based on PMG estimation outcomes

(Kassouri et al. 2020). Still, it is worth mentioning significant differences among GCC countries in terms of economic policy and resources. For instance, Bahrain and Oman have limited oil reserves and face difficulties in supporting intensive public spending, while Saudi Arabia reports an increasing population facing different structural problems (Al-Maamary et al. 2017). There are also persistent income inequalities, especially in Saudi Arabia and the United Arab Emirates forcing the government to develop social programs (Cantarero 2020). The period of high oil prices posed an unavoidable question of whether high oil prices can solve all problems. Enormous oil revenues gave a great opportunity to change the economic structures of GCC countries. However, oil and gas production has caused severe environmental problems. Gulf countries face traditional environmental challenges such as air pollution, pollution in coastal areas and marine, water scarcity, and biodiversity loss. In recent years, military conflicts and construction cause additional environmental challenges such as climate change (Sim 2020).

Dumitrescu-Hurlin panel causality results

At last, this paper employs the Dumitrescu and Hurlin Granger causality test (Table 6). These findings show feedback effects of affluence and urbanization with the anthropogenic emissions. This finding is consistent with Ahmad et al. (2019). However, a one-way causality was found flowing from electric power consumption and democratic accountability index to anthropogenic emissions (i.e., CO_2PC). This result is aligned with that of Tsai and Mezher (2020).

Conclusion and policy proposals

Unlike previous studies, this study revisits the relationship between income and anthropogenic emissions in the GCC region by incorporating the democratic accountability index, electric power consumption, and urbanization in the EKC framework. An annual frequency panel data (1990–2019) are used to estimate the long- and short-run findings by a series of advanced econometric methods, including FMOLS, LSDV, PMG, and DH causality. The long-run equilibrium was determined by using Westerlund's panel cointegration technique. The core results include the following: (1) a long-run stable equilibrium was established among anthropogenic emissions, affluence, electric power consumption, urbanization, and democratic accountability index. (2) For the whole panel, the EKC was found existent; however, the country-specific findings verified the EKC only in Saudi Arabia and

Table 6 Causal connections based on Dumitrescu-Hurlin approach

Null hypothesis			Z-score	Probability
L(PCGDP)	≠	$L(CO_2PC)$	3.837	0.000
$L(CO_2PC)$	≠	L(PCGDP)	1.976	0.048
L(EPPC)	≠	$L(CO_2PC)$	3.817	0.000
$L(CO_2PC)$	≠	L(EPPC)	0.761	0.447
L(URB)	≠	$L(CO_2PC)$	5.145	0.000
$L(CO_2PC)$	≠	L(URB)	1.922	0.055
DEM	≠	$L(CO_2PC)$	3.151	0.002
$L(CO_2PC)$	≠	L(DEM)	1.177	0.239

Source: Computed by the authors

Bahrain. In contrast, the other countries had a U-shaped linkage existent. (3) The democratic accountability index and electric power consumption escalated the anthropogenic emissions. (4) Urbanization negatively contributed to anthropogenic emission. These findings were robust across the three estimators in terms of the linkages' nature; nevertheless, the parameter estimates differed slightly in terms of magnitudes. (5) The short-run causality imparted that income and urbanization revealed bidirectional causality with the anthropogenic emissions, whereas unidirectional causal connection was stemming from electric power consumption and democratic accountability index to anthropogenic emissions.

The positive coefficient of democratic accountability index shows that GCC governments performed poorly in placing the environmental issues on the political agenda. The environmental degradation impact of democratic accountability index demonstrates that the GCC governments remained focused on using non-renewable oil resources and gave the least attention to the region's environmental quality. In order to reverse this poor environmental performance, these governments are suggested to promote renewable energy utilization. Unlike these findings, the negative coefficient with urbanization shows that GCC economies are strongly committed to sustainable development and tend to develop many strategies that support sustainable urban agendas. Growing electric power consumption in coexistence with environmental issues presents a critical challenge for the GCC region. Addressing the adverse impact of fossil fuels and their shortage, the Gulf region's strong dependence on oil and gas is not an appropriate long-term solution. In this regard, Kirikkaleli and Adebayo (2021) and Ozer and Mensah (2015) recommended renewable solutions to deal with environmental deterioration. Therefore, it is critical to plan technologies based on renewable energy that can help overcome future issues. It has been argued that special attention has been given to diversifying the sources of electrical power. In this context, nuclear energy comes into the picture. It is also worth mentioning that solar power generation has great potential in the GCC region (Alnaser and Alnaser 2011). Despite this potential, solar power has not been a significant contributor to the GCC's energy mix (Omidvarborna et al. 2018).

Since the world is in the transition to renewables, the GCC region has to extend efforts to look for more green energy sources and diversify their energy mix. In this respect, the Gulf region has started recognizing the climate change issues and is trying to develop solutions based on renewable energy. For instance, Abu Dhabi's Masdar City initiative can be taken as an example of such efforts. The other GCC countries should follow such initiatives. This city is one of the world's most sustainable urban areas made up of clean technology. The GCC region should also support the development of alternative technologies for electricity generation to put the region on the path of climate change mitigation for meeting the SDGs.

Availability of data and materials All data generated or analyzed during this study are included in this article.

Author contribution ES: conceptualization and writing-original draft. MA: writing-review and editing, visualization, and software. AM: formal analysis, data handling, and methodology.

Declarations

Ethics approval and consent to participate Not applicable

Consent for publication Not applicable

Competing interests The authors declare no competing interests.

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