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Is the long-run relationship between economic growth, electricity consumption, carbon dioxide emissions and financial development in Gulf Cooperation Council Countries robust?

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ABSTRACT

The relationship between carbon dioxide emissions, economic growth, electricity consumption and financial development in the Gulf Cooperation Council (GCC) countries is investigated in this study using panel data for the period of 1980–2012. A number of econometric techniques: dynamic ordinary least squares (DOLS), fully modified ordinary least squares (FMOLS) and the dynamic fixed effect model (DFE) are applied in order to estimate the long-run relationship between the variables. The long-run relationship is found to be robust across these different econometric specifications. No significant short-run significant relationship was observed. Electricity consumption and economic growth have a positive long run relationship with carbon dioxide (CO_2) emissions whilst a negative and significant relationship was found between CO_2 emissions and financial development. The findings imply that electricity consumption and economic growth stimulate CO_2 emissions in GCC countries while financial development reduces it. Granger causality results reveal that there is a bidirectional causal link between economic growth and CO_2 emissions and a unidirectional causal link running from electricity consumption to CO_2 emissions. However, there is no causal link between financial development and CO_2 emissions. Also, impulse response and variance decomposition analysis outline forecasted impacts of economic growth and electricity consumption on future CO_2 emissions.

Contents

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1. Introduction

Economic development through economic growth is characterized by the usually close relationship with increasing levels of electricity usage and energy more generally, as well as an associated increase in carbon dioxide emissions (CO_2). Additionally, an increase in the level and breadth of a country's financial markets to fund economic development is commonly witnessed. The extent of the influence and the interrelationship of these variables does though vary from country to country.

In this study these relationships are investigated for the six Gulf Cooperation Council countries (GCC): Saudi Arabia, United Arab Emirates (UAE), Qatar, Bahrain, Kuwait and Oman. All of these countries have experienced rapid economic growth over the past 40 years due mainly to their vast oil and gas reserves. These include approximately 40% of the world's proven oil reserves and approximately 25% of the world's natural gas reserves. They contribute approximately 8% of world CO_2 emissions [6]. Given the pivotal role of oil and gas in driving the world economy and the rapid increase in economic activity worldwide over the past 40 years, it is perhaps unsurprising that the GCC countries are amongst the highest per capita carbon dioxide (CO_2) country emitters [19].

The rapid level of economic development in the GCC countries has been associated with high rates of economic growth, electricity consumption and CO_2 emissions. Rates of economic growth and per capita electricity consumption have surpassed the levels of the major developed economies of the Organization of Economic Cooperation and Development countries (OECD) [56].

The impact of the 1970s oil shocks upon the energy-mix of the major developed economies was such that it negated the otherwise strong previous association between CO_2 emissions and economic growth as they sought to insulate their economies from high oil and gas prices. This influence was absent in the GCC countries as their governments used their cheap and abundant energy to rapidly develop their economies. This rapidly growing domestic demand for energy in the GCC countries was particularly evidenced for electricity. This situation has now led to three of the six GCC countries being the world's highest CO_2 emitters. Given this scenario, the regions' commitment to sustainable energy policies appears to be a priority.

This study investigates the short and long-run relationships amongst economic growth, electricity consumption, CO_2 emissions and financial development in the region and also determines the causal direction between the variables. Relatively little attention has been paid to the environmental sustainability of this region despite their being significant sources of global energy supply and the potential impacts of this consumption on the environment. This study is an attempt to fill this gap and more importantly, offers a discussion on policy options to achieve sustainability in regional energy systems.

This study contributes primarily by focusing exclusively on the GCC countries and a discussion of solutions to ensure environmental sustainability in the region. A secondary contribution is methodological as it applies a number of sophisticated econometric techniques: the dynamic ordinary least squares (DOLS), the fully modified ordinary least squares (FMOLS) and the dynamic fixed effect model (DFE) to estimate the long-run relationship between the variables. Also panel Granger causality is employed to determine the causal direction between the variables. The robustness of the causal link is checked by the Innovation Accounting Approach (IAA) that consists of impulse response functions and variance decompositions. Therefore, the objective of this study is to assess the interrelationship of the variables of interest in the GCC countries over the period 1980–2012.

The rest of the paper is structured as follows: Section 2 contains the literature review while Section 3 is dedicated to the discussion of the model and the estimation methods used. Section 4 presents the results whilst Section 5 offers a discussion of the results. The paper ends with conclusions, policy implications and recommendations in Section 6.

2. Literature review

2.1. Literature review on CO_2 emissions, energy consumption and economic growth

The recent literature has focused on the relationship between energy consumption, environmental pollution and economic growth. Many panel data and time series studies have been done on the relationship between these variables. Saboori et al. [42] investigated and estimated the bi-directional long-run relationship between energy consumption, carbon dioxide (CO_2) emissions and economic growth in the road transport sector of all OECD countries. Using the Fully Modified Ordinary Least Squares (FMOLS) method, this study confirmed that there is a positive significant bi-directional relationship between CO_2 emissions and economic growth, road sector energy consumption and economic growth, and between CO_2 emissions and road sector energy consumption. Also the authors found that most of the CO_2 emissions occurred as a result of energy consumption. In addition, the study stressed the need to shift to other options for energy, such as biofuel, renewable and nuclear energy, and the importance of long-run policies that aim to enhance energy efficiency. Hamdi et al. [16] examined the relationship between electricity consumption, foreign direct investment, capital and economic growth in the case of Bahrain. Their causality analysis supported the feedback effect between electricity consumption and economic growth. Cowan et al. [12], in a study of the BRICS countries, found support for the neutrality hypothesis for Brazil, India and China, indicating that there is no association between electricity consumption and economic growth. However, regarding the GDP–CO_2 emissions relationship, a feedback hypothesis for Russia, that is a one-way Granger causality running from GDP to CO_2 emissions, and a reverse relationship were found for Brazil both resulting in inconclusive policy implications.

Sbia et al. [46] investigated the empirical relationship between foreign direct investment, clean energy, trade openness, carbon emissions and economic growth using time series data for the United Arab Emirates (UAE). They found that energy demand had negative relationship with foreign direct investment, trade openness and carbon emissions while economic growth and clean energy stimulated energy consumption. In the case of Saudi Arabia, Alkhathlan and Javid [2] study revealed a positive relationship between CO_2 emissions and economic growth. They also concluded that electricity produces less pollution than other sources of energy. Hamdi and Sbia [17] examined the causal relationship between carbon dioxide emissions, energy consumption and real output for a panel of Gulf Cooperation Council (GCC) countries namely Bahrain, Kuwait, Saudi Arabia, Qatar and United Arab Emirates over the period 1980–2009. Their empirical exercise supported the presence of Environmental Kuznets Curve (EKC) hypothesis for these countries only in the long-run. They also found bidirectional causality between carbon emissions and energy usage in the short-run. Ozcan [32] tested the EKC hypothesis for 12 Middle East countries using panel data for the period 1990–2008. The study provided evidence for a U-shaped EKC for five countries and an inverted U-shaped curve for three countries. No causal link between income and CO_2 emissions was observed for the other four countries. The direction of causality was mixed for different countries. Al-Mulali and Tang [4] tested the pollution haven hypothesis for the GCC countries. In other words, they investigated the effect of FDI on CO_2 emissions. Their results suggested that increased FDI reduces CO_2 emissions. Also the study reported that energy consumption and GDP growth stimulate CO_2 emissions. Liao and Cao [24], in a large panel of 132 countries, revealed that factors like urbanization, population density, trade, energy mix, and economic environment affect the level of CO_2 emissions.

Al-Mulali [5] undertook a large time series study involving seven different regions – East Asia and Pacific; Eastern Europe and Central Asia; Latin America and the Caribbean; Middle East and North Africa; South Asia; Sub-Saharan Africa; and Western Europe. Using the Fully Modified Ordinary Least Squares (FMOLS) method, the authors investigated the relationship between urbanization, energy consumption and CO_2 emissions. Their results indicated a positive long-run relationship between the variables in six of the regions, while findings varied for the remaining region. Some of the regions demonstrated a negative relationship between the variables, while others – especially the low income countries – did not show any relationship at all. Ozturk and Acaravci [33] studied the relationship between income, energy consumption, CO_2 emissions and employment in Turkey. They found that neither CO_2 emissions per capita nor energy consumption per capita Granger-cause real GDP growth per capita.

The literature studying the relationship between CO_2 emissions, energy consumption and economic growth involving only the GCC countries is relatively scarce, although there have been several studies on the Association of Petroleum Exporting Countries (APEC), as well as the Middle East and North African (MENA) countries, and high income countries which include all or some of the GCC countries. The study of Omri [31] on 14 MENA countries found that there is a bi-directional causal link between energy consumption and economic growth in the region. Ozcan [32] tested 12 Middle East countries and found the EKC hypothesis supported in only three countries and in a further six countries it found no support and no causal link was found in the other three countries. Arouri et al. [7], in a study of 12 MENA countries, showed that energy consumption has a positive and significant impact on CO_2 emissions and that real GDP demonstrates a quadratic relationship with CO_2 emissions. Narayan and Popp [28] found that the EKC hypothesis was not supported for a panel of 43 countries including Middle Eastern countries and observed that for the Middle Eastern panel, the income elasticity in the long run is smaller than the short run estimate implying that an increase in income causes a decline in CO_2 emissions. Jaunky [22] tested the EKC hypothesis for 36 high income countries including three MENA countries – Bahrain, Oman and UAE, with the results indicating that CO_2 emissions decline with a rise in income in the long run. Soytas and Sari [53] investigated the association between carbon emissions, income, energy and total employment in five selected OPEC countries, including Saudi Arabia, and found a cointegrating relationship between the variables.

2.2. Literature review on CO_2 emissions and financial development

Chang [11] examined the non-linear effects of financial development and income on energy consumption. The study used five indicators of financial development for a panel of 53 countries for the period 1999–2008. The sample was split into two regimes: high income and non-high income countries. The findings indicate that energy consumption increases with higher levels of financial development when financial development is measured as the share of GDP of private and domestic credit. Ziaei [60] investigated the effects of two indicators of financial development (credit and stock markets) on energy consumption and CO_2 emissions. The results reveal that financial development reduces CO_2 emissions when the stock market is considered as an indicator of financial development. Boutabba [10] examined the long-run equilibrium relationship and causal link among CO_2 emissions, financial development, energy consumption and trade openness for India. The findings indicate a positive significant long-run impact of financial development on CO_2 emissions, that is, financial development increases CO_2 emissions in an unidirectional causal link running from financial development to CO_2 emissions. Omri et al. [30] investigated the causal link between economic growth, financial development and CO_2 emissions in a global panel of 54 countries. Their findings indicate a bi-directional causal link between economic growth and CO_2 emissions for the sub panels of Middle East, North Africa and Sub Saharan countries and a unidirectional causality running from CO_2 emissions to economic growth for other regions.

Ozturk and Acaravci [34] found that an increase in foreign trade to GDP ratio results an increase in per capita CO_2 emissions and the financial development variable has no significant effect on per capita CO_2 emissions in the long run for Turkey. These results also support the validity of the EKC hypothesis in the Turkish economy. Shahbaz et al. [49] in a time series study applied the ARDL bounds testing approach to cointegration to examine the influence of financial development on CO_2 emissions in Malaysia. Their findings indicate a positive and significant relationship between the variables. Their findings imply that an economy with more developed financial markets tend to attract more investment and thus facilitate more industrialization which contributes towards higher level of energy consumption eventually leading to higher level of CO_2 emissions. Shahbaz et al. [50] in another study investigated the relationship amongst economic growth, energy consumption, financial development, trade openness and CO_2 emissions in Indonesia. Their results confirms a long-run cointegrating relationship among the variables. The study further reports that financial development reduces CO_2 emissions, in other words, financial development improves environmental degradation levelsIn a recent panel study [3] found that financial development was one of the factors that increased energy consumption in GCC countries. The results further observed a cointegrating relationship between GDP, urbanization, total trade and financial development. Financial development was found to stimulate energy consumption and CO_2 emissions in sub Saharan African countries [5] through an increase of investment in energy intensive industries whilst Shahbaz and Lean [47] obtained similar results for Tunisia.

Zhang [59] investigated the impact of financial development on CO_2 emissions for China and found financial development was a significant factor. Sadorsky [43] examined the effect of financial development on energy consumption for a panel of nine Central and Eastern European economies. The findings supported the positive influence of financial development on energy consumption. Sadorsky observed similar findings in an earlier study [44] that investigated the effect of financial development on energy consumption in emerging economies. Tamazian and Rao [55] recognized financial development as an important driver of environmental performance. They argued that a more financially developed market would provide more resources for environmental projects at a cheaper price. Tamazian et al. [54] found that a high degree of financial development is associated with better environmental conditions. Jalil and Feridun [21] found that financial development reduces CO_2 emissions whilst Zhang and Cheng [58] found the opposite in these two China studies. Yuxiang and Chen [57] argued that a country with a more developed and sound financial system would enable industries to adopt and use advanced state-of-the-art technologies that are less carbon intensive. They further suggested that financial development helps economies enforce environmentally friendly regulations.

Overall the review on the relationship between financial development and CO_2 emissions suggests that the results are mixed although most of the investigations support the view that higher levels of financial development is positively associated with declining levels of CO_2 emissions. As seen from the literature, there is a limited number of studies for the GCC countries on this issue. Therefore, this study aims to fill this gap in the literature.

3. Empirical model and econometric methods

An econometric model of the following form is estimated:

$$C_{it} = \beta_i + \beta_1 \ln E_{it} + \beta_2 \ln Y_{it} + \beta_3 FD_{it} + \varepsilon_{it} \quad (1)$$

The coefficients, β_1 and β_2 represent the long run elasticity estimates of CO_2 emissions with respect to energy consumption and per capita GDP, as an increase in electricity consumption and income are expected to cause an increase in CO_2 emissions. The effect of financial development on CO_2 emissions cannot be anticipated at this stage as the literature offers inconclusive evidence about this relationship.

To estimate the model, the following actions were taken in a step wise process: (i) a cross-sectional dependence (CD) test was performed to verify whether there is cross-sectional dependence across the panel; (ii) once cross-sectional dependence is observed, an appropriate panel unit root test (i.e. CIPS) was conducted to examine the stationarity of the series; (iii) the Pedroni cointegration test which verifies the long-run relationship among the variables was then conducted; (iv) panel DOLS and panel FMOLS were employed to estimate the long-run relationship while the DFE estimation technique was applied to estimate the short-run and long-run relationships among the variables, (v) a VECM Granger causality test was conducted to assess causality between the variables and finally (vi) the robustness of the causal direction of the relationship was checked by using an Innovation Accounting Approach (IAA) through impulse response functions and variance decomposition analysis.

To investigate the relationships, data for the following variables were sourced:

- per capita CO_2 emissions (C)
- per capita electricity consumption (E)
- per capita real GDP (Y)
- financial development (FD) – domestic credit available to the private sector as share of GDP.

The World Development Indicators database 2013 was the source of the data for all six countries [56]. Real GDP per capita (Y) which is measured at constant 2000 US$ was used, per capita electricity use (kWh) and per capita CO_2 emissions were estimated by dividing total electricity and CO_2 emissions by the mid-year population. The variables were then transformed into natural logs. This transformation was intended to overcome the problem of heteroscedasticity between the variables.

3.1. Testing for unit roots

It is argued that [8] long-run parameters are likely to demonstrate cointegrating relationships among a set of I(1) variables. In other words, it is expected that the macroeconomic variables in the model will be characterized by a unit root process [29]. Therefore, determining the order of integration of the variables is the next priority in estimation and the conducting of unit root tests for all variables achieves that aim. Cross-sectional dependence is to be expected amongst this group of six homogenous countries. An examination of the presence of contemporaneous correlation across the countries was achieved by implementing a cross-sectional dependence (CD) test developed by Pesaran [39] who defines the CD statistic as

$$CD = \left[\frac{TN(N-1)}{2}\right]^{1/2} \bar{\hat{\rho}}, \quad (2)$$

where

$$\bar{\hat{\rho}} = \left(\frac{2}{N(N-1)}\right) \sum_{i=1}^{N} \sum_{J=i+1}^{N} \hat{\rho}_{iJ}$$

in which $\hat{\rho}_{ij}$ is the pair-wise cross-sectional correlation coefficients of residuals from the conventional ADF regression; T and N are sample and panel sizes, respectively.

Because the CD test indicates the presence of cross-sectional dependence in the panel, the following cross-sectionally augmented Dickey–Fuller (CADF) regression was used:

$$\Delta Y_{it} = \alpha_{it} + K_i t + \beta_i Y_{it-1} + \gamma_i \bar{y}_{t-1} + \phi_i \Delta \bar{y}_t + \varepsilon_{it},$$
$$t = 1 \ldots T \text{ and } i = 1 \ldots N \quad (3)$$

where

$$\bar{y}_t = N^{-1} \sum_{i=1}^{N} Y_{it}$$

is the cross-sectional mean of y_{it}. The purpose of including the cross-sectional mean in the above equation is to control for contemporaneous correlation among y_{it}. This is a modified version of the IPS test [20] and is referred to as the cross-sectionally augmented IPS (CIPS) test [40]. The null hypothesis of the test can be expressed as H_0: $\beta_1 = 0$ for all i against the alternative hypothesis H_0: $\beta < 0$ for some i. The test statistic provided by Pesaran [40] is given as

$$CIPS(N,T) = N^{-1} \sum_{i=1}^{N} t_i(N,T)$$

where t_i (N, T) is the t statistic of β_i in Eq. (2). The critical values of CIPS (N, T) are available in Table II(c) of Pesaran [40].

3.2. Panel cointegration

If the results from the CIPS unit root test indicate a cointegrating relationships in the dataset then several panel cointegration tests suggested by Pedroni [35,36] need to be conducted. The Pedroni cointegration test controls for country size and heterogeneity which allows for multiple regressors of the cointegration vector to vary across various panel sections [36]. Seven panel cointegration statistics for seven tests are obtained. Four are within-dimension tests, whilst three are between-dimension or group statistics approach. The methodology used for the panel cointegration is reproduced in [45].

3.3. Estimation of panel cointegration regression

If a cointegrating relationship between the variables is found, the next step is to estimate the long-run parameters. Since in the presence of cointegration, OLS leads to spurious coefficients, a number of alternative econometric methods are proposed. One such method is the panel dynamic OLS (DOLS) which is believed to provide better results for cointegrated panels. However, one major weakness of DOLS [23] is that it does not consider the cross sectional heterogeneity issue. Pedroni [37,38] proposed the fully modified OLS (FMOLS) estimator for cointegrated panels which takes into account the cross sectional heterogeneity, endogeneity and serial correlation problems. The FMOLS technique is also believed to provide consistent estimates in small samples [38].

Table 1
Summary statistics of the variables.

	LCO2	LGDPC	LFD	LEPC
Mean	3.044914	10.00954	1.534847	3.844567
Median	3.117565	9.864770	1.551185	3.918153
Maximum	4.227340	11.31380	1.971023	4.241647
Minimum	1.492100	8.711520	0.833438	2.794986
Std. dev.	0.614045	0.640451	0.209025	0.291089
Skewness	−0.461721	0.116449	−0.453239	−1.042773
Kurtosis	2.913923	1.591193	3.473983	4.047534
Jarque-Bera	6.737876	15.97199	8.196517	42.66683
Probability	0.034426	0.000340	0.016602	0.000000
Sum	572.4439	1881.794	288.5513	722.7785
Sum sq. dev.	70.50864	76.70310	8.170278	15.84502
Observations	188	188	188	188

Table 2
CIPS unit root test results.

	P	CD	CIPS	CIPS (1st diff.)
LGDPC	0.488	2.09**	−1.501	−2.637***
LCO_2	0.298	−0.52	−1.747	−2.664***
LEPU	0.832	18.50***	−1.283	−2.860***
FD	0.506	11.03***	−1.811	−3.006***

*Notes:** , ** and *** denote level of significance at 1%, 5% and 10% respectively.

Table 3
Pedroni residual cointegration test.

Alternative hypothesis: common AR coefs. (within-dimension)				
	Statistic	Prob.	Weighted	
			Statistic	Prob.
Panel v-statistic	2.679511	0.0037	1.777153	0.0378
Panel rho-statistic	−1.588999	0.0560	−0.742916	0.2288
Panel PP-statistic	−2.961571	0.0015	−1.791329	0.0366
Panel ADF-statistic	−1.357293	0.0873	−0.834728	0.2019
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic	Prob.		
Group rho-statistic	−0.907086	0.1822		
Group PP-statistic	−2.939609	0.0016		
Group ADF-statistic	−1.579396	0.0571		

Table 4
Results from panel Dynamic Ordinary Least Squares (DOLS) estimation.

Variable	Coefficient	Std. error	*t*-Statistic	Prob.
LEC	0.648209	0.100480	6.451117	0.0000
LGDPC	0.390644	0.202823	1.926033	0.0562
LFD	−0.006200	0.002251	−2.754503	0.0067
R-squared	0.949922	Mean dependent var		3.041422
Adjusted *R*-squared	0.926752	S.D. dependent var		0.603062
S.E. of regression	0.163215	Sum squared resid		3.569641
Long-run variance	0.039696			

3.4. Dynamic fixed effect model

One common shortcoming of both the DOLS and FMOLS methods is that they do not estimate short-run relationships [27]. Alternative methods such as the pooled mean group (PMG) regression, mean group regression (MG) and the dynamic fixed effect (DFE) model are available to consider different levels of heterogeneity across countries while estimating both the short-run and the long-run effects simultaneously. The DFE imposes homogeneity restrictions on the long-run and short-run coefficients while allowing the intercept to vary. Since GCC countries are characterized by similar macroeconomic structures (oil-based economies), the application of the DFE model is justified in this case. There may be different types of temporary shocks in different GCC countries due to local laws, regulations and political regimes and this heterogeneity is captured by country-specific intercepts.

Table 5
Results from fully modified ordinary least squares (FMOLS) estimation.

Variable	Coefficient	Std. error	*t*-Statistic	Prob.
LGDPC	0.405094	0.131383	3.083311	0.0024
LFD	−0.655508	0.168888	−3.881318	0.0001
LEPC	1.338018	0.169979	7.871661	0.0000
R-squared	0.907085	Mean dependent var.		3.050169
Adjusted *R*-squared	0.902738	S.D. dependent var.		0.602068
S.E. of regression	0.187766	Sum squared resid.		6.028805
Durbin–Watson stat	1.597326	Long-run variance		0.075695

In practice, contemporaneous correlation across residuals arises from omitted common factors. To eliminate the influence of these common factors allowance for time-specific effects in the estimated regressions are made. In order to comply with the requirements for standard estimation and inference, Eq. (1) is embedded into an ARDL (p, q) model. In error correction form, this can be written as follows:

$$\Delta(y_i)_t = \sum_{j=1}^{p-1} \gamma_j^i \Delta(y_i)_{t-1} + \sum_{j=0}^{q-1} \delta_j^i \Delta(x_i)_{t-1} + [(y_i)_{t-1} - \beta_1^i (X_i)_{t-1}]] + \beta_0^i + \mu_t + \varepsilon_{it} \quad (4)$$

where y_i is the dependent variable (CO_2 emissions), Xs are independent variables (electricity consumption, economic growth and financial development), γ_j^i and δ_j^i are short run coefficients, β_1^i are the long-run coefficients, β_0^i, μ_t and ε_{it} are country-specific fixed effects, time-specific effects and stochastic error term respectively.

3.5. Panel Granger causality test

If the variables are found to be first difference stationary [I(1)], then to assess the causal direction of the relationship between them further tests are required [14]. Information about the exact direction of the causal link enables a more nuanced discussion of the policy implications of the findings [48].

3.6. Impulse response and variance decomposition

One major weakness of the VECM Granger causality test is that it is unable to provide reliable estimates of the causal strength of relationship between variables beyond the selected sample period. Another limitation is that it provides only the direction of the relationship, not the corresponding sign. To overcome these limitations, this study applies the Innovation Accounting Approach (IAA) which consists of variance decomposition and generalized impulse response functions. The generalized impulse response function is preferred over the simple Choleski fractionalization impulse response analysis as the generalized impulse response function is insensitive to the order of the VECM. It also indicates whether the impacts of innovations are positive or negative or whether they have a short-run or long-run effect. The general representation of this procedure is available in the seminal works of Sims [51,52] and Bernanke [9]. Although impulse response function traces the effect of a one standard deviation shock on the current and future values of all the endogenous variables through the dynamic structure of VECM, it does not provide the magnitude

Table 6
Results from dynamic fixed effect (DFE) and mean group (MG) estimations.

Variables	Dynamic fixed effect		Mean group	
	Long run	Short run	Long run	Short run
Error correction		−0.402***		−0.499***
		(0.0562)		(0.161)
Δ GDP per capita		0.217		0.525***
		(0.254)		(0.158)
Δ Electric power consumption		0.885***		0.163
		(0.120)		(0.220)
Δ Financial development		0.104		0.0378
		(0.177)		(0.0784)
GDP per capita	0.405*		3.372	
	(0.013)		(2.570)	
Electric Power Consumption	0.617***		−0.737	
	(0.107)		(0.850)	
Financial Development	−0.131		−0.0354	
	(0.058)		(0.0761)	
Constant		−2.448***		−4.168**
		(0.785)		(2.044)
Observations	192	192	192	192

*Notes:** , ** and *** denote level of significance at 1%, 5% and 10% respectively.

of such effect. Consequently, the variance decomposition method is employed to examine this magnitude.

Variance decomposition [41] measures the percentage contribution of each innovation to *h*-step ahead of the forecast error variance of the dependent variable and provides a means to determine the relative importance of shocks in explaining the variation in the dependent variable. Engle and Granger [13] argued that the variance decomposition approach produces more reliable results as compared to those from other traditional approaches.

4. Results

Table 1 reports the summary statistics which shows that the data are well behaved. The standard deviations show that the data are homogeneous.

Table 2 presents the results of the CD test and CIPS unit root test. The CD test results confirms cross sectional dependence in two of the three series (GDPC and energy consumption). The CIPS unit root test proves all variables to be stationary at first difference, i.e. I(1).

The Pedroni panel cointegration test results are presented in Table 3. Six of seven tests reject the null hypothesis of no cointegration. The group rho statistic has the best statistical power of all the tests [15], and it also rejects the null of no cointegration. Therefore, there is evidence that there is a long run cointegrating relationship among the variables.

Table 4 presents the results from the DOLS estimates. The estimates suggest positive and significant long-run relationships of electricity consumption and economic growth with CO_2 emissions. Financial development demonstrates a negative and significant association with CO_2 emissions.

FMOLS estimates which produced similar results to DOLS but with slightly different coefficient values are reported in Table 5. The FMOLS results indicate a positive and highly significant relationship between electricity consumption and economic growth with CO_2 emissions. Financial development has a highly significant negative effect on CO_2 emissions which means financial development reduces CO_2 emissions.

Table 6 provides the results from the DFE estimation. Overall results suggest that the long run coefficient of CO_2 emissions to electricity consumption is 0.61 and this is significant at the 5% level. In other words, a 1% increase in electricity consumption enhances CO_2 emissions by 0.61% in the long run. There is also a significant and positive long run relationship between economic growth and CO_2 emissions. The long run coefficient of CO_2 emissions to economic growth is 0.40 which means a 1% increase in real GDP per capita causes a 0.40% increase in CO_2 emissions. There is no significant short-run relationship among these variables.

Table 7
Panel VECM Granger causality.

Excluded	Chi-sq	df	Prob.
Dependent variable: *D*(*LCO2*)			
D(LEPU)	5.287331	1	0.2215
D(LGDPC)	0.329650	1	0.5659
D(FD)	6.121831	1	0.0134
All	11.23275	3	0.0105
Dependent variable: *D*(*LEPU*)			
D(LCO2)	7.352636	1	0.0067
D(LGDPC)	5.152295	1	0.0232
D(FD)	0.142911	1	0.7054
All	11.69896	3	0.0085
Dependent variable: *D*(*LGDPC*)			
D(LCO2)	0.882288	1	0.3476
D(LEPU)	1.985224	1	0.1588
D(FD)	0.867994	1	0.3515
All	2.547835	3	0.4667
Dependent variable: *D*(*FD*)			
D(LCO2)	2.618363	1	0.1056
D(LEPU)	2.679576	1	0.1016
D(LGDPC)	0.196280	1	0.6577
All	3.735083	3	0.2915

In Table 7, the panel vector error correction model (VECM) Granger causality findings are reported. There is a bidirectional causal link between energy consumption and CO_2 emissions and a unidirectional causal link from economic growth to energy consumption. The relationship between economic growth and CO_2 emissions has no causal link.

From Fig. 1, it can be seen that the standard deviation of per capita CO_2 emissions leads to a positive increase in future per capita CO_2 emissions. The response of per capita CO_2 emissions to the increases in electricity consumption and per capita GDP demonstrate

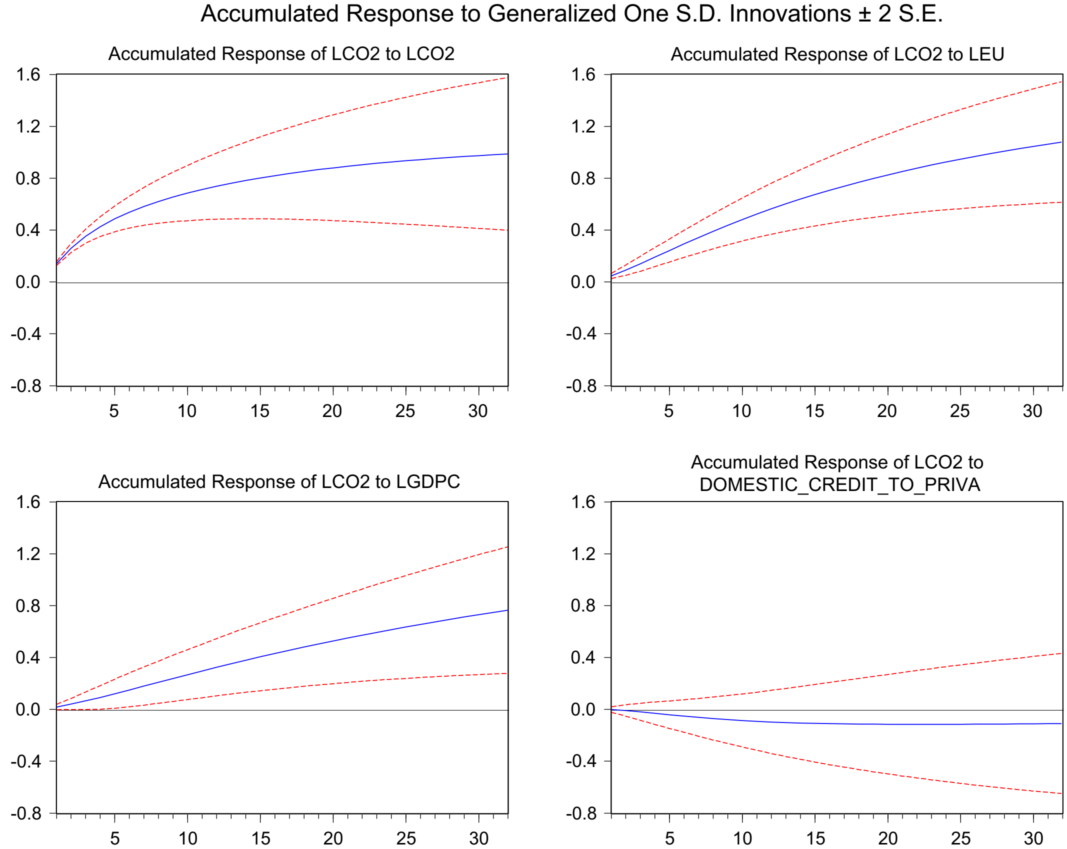

Fig. 1. Impulse responses of CO_2 emissions to independent variables.

Table 8
Variance decomposition of CO_2 emission for GCC countries: 1980–2012.

Period	S.E.	LCO2	LEU	LGDPC	DOMESTIC_CREDIT_TO_PRIVA
1	0.141899	100.0000	0.000000	0.000000	0.000000
2	0.184542	99.69382	0.117580	0.146193	0.042407
3	0.207631	98.49373	1.021031	0.386978	0.098266
4	0.222774	96.56938	2.526875	0.763157	0.140583
5	0.234046	94.24441	4.339306	1.250446	0.165842
6	0.243119	91.78623	6.232153	1.805594	0.176026
7	0.250761	89.36774	8.066943	2.389722	0.175592
8	0.257369	87.08277	9.772029	2.975648	0.169548
9	0.263173	84.97231	11.31842	3.547021	0.162251
10	0.268323	83.04643	12.70142	4.095226	0.156919
11	0.272926	81.29900	13.92888	4.616515	0.155613
12	0.277064	79.71645	15.01417	5.109955	0.159422
13	0.280802	78.28272	15.97245	5.576120	0.168714
14	0.284191	76.98166	16.81866	6.016312	0.183360
15	0.287276	75.79829	17.56666	6.432122	0.202927
16	0.290094	74.71916	18.22883	6.825195	0.226808
17	0.292674	73.73249	18.81608	7.197110	0.254327
18	0.295044	72.82801	19.33787	7.549329	0.284796
19	0.297227	71.99686	19.80240	7.883180	0.317560
20	0.299240	71.23135	20.21677	8.199860	0.352015
21	0.301102	70.52484	20.58709	8.500444	0.387625
22	0.302827	69.87154	20.91864	8.785902	0.423923
23	0.304427	69.26639	21.21600	9.057107	0.460509
24	0.305915	68.70496	21.48314	9.314856	0.497045
25	0.307299	68.18335	21.72352	9.559875	0.533255
26	0.308589	67.69810	21.94016	9.792832	0.568911
27	0.309793	67.24614	22.13569	10.01434	0.603833
28	0.310917	66.82473	22.31241	10.22498	0.637879
29	0.311968	66.43142	22.47235	10.42529	0.670943
30	0.312951	66.06400	22.61730	10.61576	0.702943
31	0.313872	65.72048	22.74883	10.79687	0.733827
32	0.314734	65.39905	22.86833	10.96906	0.763557

the expected signs but with different magnitudes. The accumulated response of per capita CO_2 emissions to electricity consumption is positive and significant and to GDP per capita is also positive and significant. The response of per capita CO_2 emissions to future shocks of financial development is negative and significant. Thus, these findings are supportive of all earlier econometric estimations.

Results from the variance decomposition analysis are reported in Table 8. The study allows for a 32-year forecasting horizon. Interestingly, at the 5-year forecasting horizon, about 94% of the one-step forecast variance in per capita CO_2 emissions is accounted for by its own innovations and altogether 6% is accounted for by economic growth, electricity consumption and financial development. In the long-run, the response to own innovative shocks declines to around 65% while the response of per capita electricity consumption to the shocks in per capita CO_2 emissions, economic growth and financial development are expected to rise to 35% from the first 5-year forecast horizon of 6%. Amongst the 35% of the variance, approximately 23% of variance is due to the shocks in per capita electricity consumption and around 11% variations are attributed to GDP per capita while the rest, 0.76%, is due to the shock in financial development. The findings reinforce that while per capita electricity consumption is likely to have a very strong forecasted impact on per capita CO_2 emissions, the impact of economic growth is also likely to be evident in the future. However, the forecasted impact of financial development seems to be weak.

5. Discussion

This study investigated the effects of economic growth, electricity consumption and financial development on CO_2 emissions in GCC countries using panel data for the period of 1980–2012. CIPS panel unit root tests were conducted that account for cross sectional dependence and find that all variables first difference stationary. The Pedroni cointegration test confirms a cointegrating relationship among the variables. Group DOLS and FMOLS were employed to estimate the long-run relationship among the variables. The panel econometric technique, the DFE model, was estimated to examine both the short-run and the long-run relationship between CO_2 emissions and economic growth, electricity consumption and financial development. Group DOLS and FMOLS were also employed to test the robustness of the long-run relationship among the variables. Economic growth and electricity consumption were found to have a positive significant impact on CO_2 emissions in the long-run while no significant short-run relationship between these variables was observed. The findings of the long-run association between electricity consumption and economic growth are in contrast with the results of a recent study on GCC countries [17]. Financial development was found to reduce CO_2 emissions in the long-run. A bi-directional causal link was found between economic growth and CO_2 emissions. This implies that although the GDPs of the GCC countries are largely oil based, their oil based revenues generate high incomes for their citizens and a massive influx of foreign workers both of which leads to a sharp rise in energy demand. To meet the growing energy demand, enormous amounts of electricity are generated, mostly from fossil fuel sources.

A unidirectional causal link running from electricity consumption to CO_2 emissions is found to exist. No causal link was found between financial development and CO_2 emissions. Impulse response functions and variance decomposition analysis reveal that per capita electricity consumption and economic growth will continue to impact CO_2 emissions significantly into the future while the impact of financial development is expected to be of little magnitude. Therefore, the GCC countries will have to look for alternative sources of power generation as well as undertaking measures to reduce CO_2 emissions. The overall results imply that economic growth and electricity consumption contribute towards CO_2 emissions in the GCC countries. No such relationship was found for financial development.

6. Conclusions and policy implications

This study aimed to examine the effects of economic growth, electricity consumption and financial development on CO_2 emissions in GCC countries using panel data for the period of 1980–2012. Unit root test that account for cross sectional dependence was conducted. Pedroni cointegration test confirmed a cointegrating relationship between the variables. A panel econometric technique, the DFE model, was estimated to examine both the short-run and the long-run relationship between CO_2 emissions and economic growth, electricity consumption and financial development. Economic growth and electricity consumption were found to have a positive significant impact on CO_2 emissions in the long-run while no significant short-run relationship between these variables was observed. Financial development was found to reduce CO_2 emissions in the long-run. Group DOLS and FMOLS provided evidence in support of the DFE results.

The Granger causality results suggested a bidirectional causal link between economic growth and CO_2 emissions. A unidirectional causal link running from electricity consumption to CO_2 emissions was found to exist. No causal link was found between financial development and CO_2 emissions. Impulse response functions and variance decomposition analysis revealed that per capita electricity consumption and economic growth would continue to impact CO_2 emissions significantly into the future while the impact of financial development is expected to be of little magnitude. Overall results demonstrated that economic growth and electricity consumption contributed towards CO_2 emissions in the GCC countries. No such relationship was found for financial development.

The findings of this study have very important policy implications for GCC countries for not only to be able to efficiently deal with current climate challenges but also for their post-oil future. Emissions are already causing sea levels to rise and affecting coastlines and marine lives resulting in increasing levels of salinity. This situation will eventually cause a scarcity of the availability of fresh water. The GCC countries are already running a large number of desalinization plants which are very expensive to operate and are also harmful to the environment as they need huge amounts of electricity to run.

Also, as these countries' energy supply is predicted to reduce with the passage of time, the opportunity cost of huge government subsidies on current energy consumption is likely to be more and more financially unsustainable. Although a trade-off between these opportunity costs and the political reality of these countries, which are mostly ruled by monarchies, may be difficult to envisage. Since, these countries are under potential threat as a result of their alarming levels of emissions and their responses to combating emissions appear to be inadequate so far, they cannot afford to waste time. There is a need to act promptly to promote energy efficiency and the use of renewable resources, in other words, they must do everything possible to reduce their economies dependence on fossil fuels and to introduce newer more environmentally friendly technologies to meet their energy needs.

Based on the findings of the study, it is suggested that the GCC countries should reduce CO_2 emissions by a variety of measures. There are alternative potential measures for electricity generation that will enable the region to achieve higher levels of energy efficiency. It is already evident that GCC countries can reduce CO_2 emissions and gain energy efficiency in three ways: (a) promoting carbon capture, utilization and storage (CCUS) plants, (b) promoting the use of renewable resources and (c) building nuclear energy plants.

The CCUS method has already proved its potential to reduce CO_2 emissions in the region [6]. Another recent study of Saudi Arabia also has recognized the potential of CCUS to significantly reduce CO_2 emissions [25]. The GCC countries also have clear advantage over the rest of the world in renewable resources, especially solar and wind energy. The region is characterized by an enormous amount of sunlight and wind and for more than 80% of days in a year its sky is cloud free or clear. The average solar radiation of the region is 2200 kWh (th)/m^2 [18]. Therefore, solar and wind are the two most significant potential renewable sources for energy in the region. Although, Saudi Arabia and the UAE have already been pursuing research on this potential, other GCC countries also need to recognize and tap this opportunity. It is already evident that use of solar photovoltaic (PV) can significantly save CO_2 emissions in the electricity sector of Saudi Arabia and the UAE [25,26]. Solar PV is a very good technology option for long term investment in the power sector. It will potentially enable GCC countries to achieve their renewable generation targets [26].

Building nuclear energy plants is another viable option for the GCC countries to combat emissions. Since all these countries' economies are characterized by large foreign capital reserves thanks to their oil revenues, investment in such projects should not be considered too ambitious for them. The UAE has already decided to integrate nuclear energy into its electricity generation portfolio and a recent study by Alfarra and Abu-Hijley [1] showed through a number of scenario analysis that the use of nuclear energy would not only reduce CO_2 emissions but also reduce per unit electricity generation costs.

Finally, this study recommends that the GCC countries need to significantly boost investment for research in clean energy technologies and build energy expertise. This is not only to address the prevailing climate challenges and meet their current renewable energy targets only but also to deal with further challenges in the post-oil age. Long-term investment in building a university under the potential name of 'GCC University of Energy Research and Technology' could be a vital and sustainable contribution towards the achievement of such goal.

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