Energy consumption, CO2 emissions and economic growth nexus: Evidence from panel Granger causality test

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Abstract

This paper examines the empirical causal relationship between energy consumption, CO2 emissions and economic growth for six oil-exporting countries from the Golf Cooperation Council (GCC) region over the period 2000:2011. Bootstrap panel Granger causality test approach is used which take account the cross-sectional dependency and the heterogeneity across countries. The empirical results support a bi-directional causality between economic growth and energy consumption for Bahrin and one-way Granger causality running from economic growth to energy consumption for United Emirate Arab and Qatar. Regarding to GDP-CO2 emissions nexus, a reverse relationship from CO2 to GDP for Bahrin and Kuwait is found. However, a two-way Granger causality between CO2 emissions and energy consumption for United Arab Emirate is found.
keyword: Energy consumption, CO2 emissions, economic growth, bootstrap panel causality test, Cross-sectional dependence, Heterogeneity, GCC.

1 Introduction

Energy plays a fundamental role in economic development, since it is a vital force driving all economic activities. Energy demand in most countries in the world, has grown quite significantly due to rapid urbanization and population growth. Indeed, the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) avowed that the energy demands in developing countries are projected to growth for around 87 percent by 2030 (UNEP, 2011). Therefore, the rapid economic growth was guaranteed by largely functioning industries which requires more energy consumption, though it leads to environmental degradation. There is still conflict on whether energy consumption is a stimulating factor for, or a result of, economic growth.

The main objective of this paper, is to examine the relationship between CO2 emission, energy consumption and economic growth for a panel of 6 countries during 1965:2014. For this reason, we used, as investigate technique, a panel data model. The following study is different from the existing on the impact of economic growth and CO2 emission on energy consumption. We use a

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bootstrap panel Granger (1969) non causality test which take account the existence of cross-sectional dependence and the heterogeneity across countries. This approach is proposed by Kónya (2006).

The remainder of paper is structured as follows. The section 2 presents the empirical literature review. In section 3, we provide a description of the used model and the data. The methodology is given in the section 4. The section 5 shows empirical results and discussion.

2 Literature review

In the literature, there are several studies, theoretical and empirical, which put the accent on the relationship between energy consumption, economic growth, and the emission of CO2 that may exist. Empirically it has been tried to find the direction of causality between energy consumption and economic activities for some countries employing the Granger Test, ECM and other techniques. In recent papers, Zhang and Lin (2012) chowed that urbanization increases energy consumption and CO2 emissions in China using panel estimation. They proves that the effects of urbanization on energy consumption vary across regions and decline continuously from the western region to the central and eastern regions. Shyamal and Rabindra (2004) examined the different direction of causal relation between energy consumption and economic growth in India through a co-integration technique combined with the Granger causality test. They find the existence of a bi-directional causality between energy consumption and economic growth. Wang et al. (2016) used a co-integration approach in China data to examine the relation between economic growth, energy consumption and CO2 emission. Granger causality test identified a bi-directional causal relationship between economic growth and energy consumption, and a uni-directional causal relationship was found to exist from energy consumption to CO2 emissions. Saidi and Hammami (2015) studied the impact of energy consumption and CO2 emission on economic growth for 58 countries. They have used simultaneous equations models estimated by the GMM-estimator and they find evidence that energy consumption has a positive impact on economic growth and that the CO2 emissions have a negative impact on economic growth.

For the Golf Cooperation Council countries, we select divers studies by Al-Mulali and Ozturk (2014), Farhani and Shahbaz (2014), Salahuddin and Gow (2014), Mohammadi and Parvaresh (2014), Alshehry and Belloumi (2015), Jammazi and Aloui (2015) and Magazzino (2016). For example, Al-Mulali and Ozturk (2014) studied the relationship between the fossil fuels electricity consumption and growth of the gross domestic product in six GCC countries for the period 1980-2012 by using the auto-regressive distributed lag (ARDL) and the TodaYamamotoDoladoLtkepohl (TYDL) methodologies. They found a bi-directional causality between fossil fuels electricity consumption and GDP growth in Bahrain and the United Arab Emirates (UAE) and one way causality from fossil fuels electricity consumption to GDP growth was found in Oman and Qatar. Farhani and Shahbaz (2014) examined the causal relationship between renewable and non-renewable electricity consumption, output and carbon dioxide (CO2) emissions for 10 Middle East and North Africa (MENA) countries. By using panel Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS), they found a unidirectional causality running from renewable and non-renewable electricity consumption and output to CO2 emissions in short-run, while in long-run, a bidirectional causality between electricity consumption and CO2 emissions was established. Salahuddin and Gow (2014) investigated the empirical relationship between economic growth, energy consumption and carbon dioxide emissions in GCC countries. They identified a positive and significant association between energy consumption and CO2 emissions and between economic growth and energy consumption both in the short- and the long-run. Mohammadi and Parvaresh (2014) focused the long-run and short-run dynamics between energy consumption and output in a panel of 14 oil-exporting countries over 1980-2007 by using panel estimation technique. They detected a bidirectional causality in both long- and short-run relation between energy consumption and output. Jammazi and Aloui (2015) examined the interplay between energy consumption, economic growth and CO2 emission for six GCC countries through wavelet window cross correlation approach. They pointed out the existence of bi-directional causality effects between energy consumption and economic growth, while a unidirectional relationship was found from energy consumption to CO2 emission. Magazzino (2016) using a time series approach, explores the relationship among real GDP, carbon dioxide (CO2) emissions, and energy use in the six Gulf Cooperation Council (GCC) countries. This paper found that energy is generally expected to play a major role in achieving economic, social, and technological progress and to complement labour and capital in production for Kuwait, Oman, and Qatar.

The above review literature on the causal relationship between energy consumption, carbon dioxide emission and economic growth shows a various findings. These divergences in results seem coming from using different data sets, various econometric techniques, sample periods and countries. The main contribution of this paper is to investigate fresh evidence to the causal relationship between energy consumption, CO2 emissions and economic growth.

3 Data description

The data were used in the analysis is annual. The data covers six GCC countries namely Saudi Arabia (KSA), Bahrin, Kuwait, Oman, United Arab Emirates (UAE) and Qatar for the period 2000:2011. It includes both energy consumption (EC) expressed in kg of oil equivalent per capita, carbon dioxide per capita (CO2) measured in metric tonnes and economic growth measured by GDP per capita in constant 2010 US dollars. The data is derived from World Development Indicators (WDI). All the variables are expressed in per capita terms and converted in logarithmic series. Table 1, Table 2 and Table 3 display the summary statistics of CO2 emissions, real GDP and electricity consumption respectively. From these tables, we find that Oman and Qatar have the lowest and highest levels of CO2 emissions respectively, and the lowest and highest of mean of real GDP respectively and the lowest and highest total electricity consumption.

	min	**max**	**mean**	**median**	**sd**	**skew**	**kurtosis**
KSA	13.50	18.98	15.90	15.85	1.79	0.20	-1.45
Bahrin	17.95	27.96	21.05	21.48	2.65	1.15	1.19
Kuwait	27.76	31.61	29.45	29.48	1.15	0.31	-1.11
Oman	8.93	20.20	13.92	13.75	3.58	0.33	-1.25
UAE	20.12	36.90	25.76	24.46	5.03	0.77	-0.50
Qatar	42.64	61.99	51.87	51.79	6.96	0.05	-1.74

Table 1: Summary statistics of CO2 emissions.

	min	**max**	**mean**	**median**	**sd**	**skew**	**kurtosis**
KSA	14232.22	20121.84	16749.86	16675.94	1904.75	0.21	-1.45
Bahrin	20101.85	22877.95	21875.42	22269.73	983.86	-0.72	-1.23
Kuwait	37153.71	49015.89	42639.86	41828.23	4841.18	0.15	-1.87
Oman	17646.72	20257.96	18806.66	18825.82	921.29	0.17	-1.59
UAE	34341.91	64133.15	51198.92	55302.98	11425.44	-0.40	-1.66
Qatar	60736.57	74448.87	66058.60	66517.26	4100.06	0.43	-0.86

Table 2: summary statistics of GDP.

	min	max	mean	median	sd	skew	kurtosis
KSA	4564.23	6603.23	5353.69	5161.16	677.51	0.46	-1.34
Bahrin	9628.85	11948.98	11223.19	11554.40	825.55	-0.84	-1.02
Kuwait	9745.93	11662.27	10523.88	10511.09	512.15	0.53	-0.32
Oman	3441.09	7155.12	5255.77	5230.93	1423.62	0.05	-1.94
UAE	7361.15	11958.48	9534.09	9311.94	1698.54	0.07	-1.77
Qatar	15230.37	22762.08	18807.53	19219.57	2448.18	-0.04	-1.47

Table 3: summary statistics of electricity consumption.

4 Methodology

In order to investigate the causal relationship between energy consumption, CO2 emission and economic growth, we follow the method so-colled the bootstrap panel causality test proposed by Kónya (2006). The bootstrap panel causality approach is able to account both cross-section dependence and cross-country heterogeneity.
To decide whether the slope coefficients are treated as homogeneous or heterogeneous to impose causality restriction on the estimated parameters, three statistical tests was selected: the Breusch and Pagan (1980) LM test, the Peasaran CD test, and the Pesaran et al. (2008) bias-adjusted LM test. The cross-country heterogeneity is tested by using the test for slope homogeneity proposed by Pesaran et al. (2008).

4.1 Cross-section dependence test

To test for cross-sectional dependency, the Lagrange multiplier (LM) test of Breusch and Pagan (1980) is used in empirical studies where $T < N$. In the case of large N panels, (Peasaran) considers a modified version of LM test called CD test. Pesaran et al. (2008) proposes a bias-adjusted normal approximation versions of Lagrange multiplier test of error cross section independence of Breusch and Pagan (1980). In this subsection, we describe these three tests.
Consider the following panel data model:

$$y_{it} = \alpha_i + \beta_i' X_{it} + \epsilon_{it}, \text{ for } i = 1, 2, \ldots, N \text{ and } t = 1, 2, \ldots, T \tag{1}$$

where i is the cross section dimension, t is the time dimension, X_{it} is $k \times 1$ vector of explanatory variables, α_i and β_i are respectively the individual intercepts and slope coefficients that are allowed to vary cross states.

4.1.1 Breursh and Pagan LM test

In the LM test, the null hypothesis of no-cross section dependence - $H_0 : Cov(\epsilon_{it}, \epsilon_{jt}) = 0$ for all t and $i \neq j$ - is tested against the alternative hypothesis of cross-section dependence $H_1 : Cov(\epsilon_{it}, \epsilon_{jt}) \neq 0$, for at least one pair of $i \neq j$. The test is based on the following LM statistic

$$LM = T \sum_{i=1}^{N-1} \sum_{t=i+1}^{N} \widehat{\rho}_{ij}^2 \tag{2}$$

where $\widehat{\rho}_{ij}^2$ is the sample estimate of pairwise correlation of the residuals from ordinary least squares (OLS) estimation of Equation 1 for each i. Breusch and Pagan (1980) show that under the null hypothesis the LM statistic is asymptotically distributed as chi-squared with $N(N-1)/2$ degrees of freedom.

4.1.2 Pesaran CD test

It is well known that the standard Breusch-Pagan LM test statistic is not appropriate for testing in large panels. To address this shortcoming, (Peasaran) proposes an alternative statistic based on the average of the pairwise correlation coefficients $\widehat{\rho}_{i,j}$:

$$CD = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{i,j} \widehat{\rho}_{i,j} \tag{3}$$

which is asymptotically standard normal for $T_{i,i} \longrightarrow \infty$ and $N \longrightarrow \infty$ in any order.

4.1.3 The bias-adjusted LM test

Pesaran et al. (2008) proposes a bias-adjusted test which is a modified version of the LM test by using the exact mean and variance of the LM statistic. The bias-adjusted LM test is

$$LM_{agj} = \sqrt{\left(\frac{2T}{N(N-1)}\right)} \sum_{i=1}^{N-1} \sum_{t=i+1}^{N} \widehat{\rho}_{ij} \frac{(T-k)\widehat{\rho}_{ij}^{2} - \mu_{Tij}}{\sqrt{\nu_{Tij}^{2}}} \tag{4}$$

where μ_{Tij} and ν_{Tij}^2 are respectively the exact mean and variance of $(T-k)\widehat{\rho}_{ij}^2$, that are provided in Pesaran et al. (2008). Under the null hypothesis with first $T \rightarrow \infty$ and then $N \rightarrow \infty$, LM_{adj} statistic is asymptotically distributed as standard normal.

4.2 Test of slope homogeneity

The second issue in panel data analysis is to decide whether or not the same coefficients are applied to each individual. It is a standard F test, based on the comparison of a model obtained for the full sample and a model based on the estimation of an equation for each individual. The F test is valid for the case where the cross section dimension (N) is relatively small and the time dimension (T) of panel is large; the explanatory variables are strictly exogenous; and the error variances are homoscedastic. In the case where $(N, T) \longrightarrow \infty$, (Pesaran and Yamagata, 2008) propose a $\tilde{\Delta}$ test, without any restriction on the relative expansion rate of N and T when the error terms are normally distributed. The $\tilde{\Delta}$ test approach includes two steps. First step is to compute the following statistic:

$$\tilde{S} = \sum_{i=1}^{N} \left(\widehat{\beta}_i - \widehat{\beta}_{WFE}\right)' \frac{x_i' M_\tau x_i}{\tilde{\sigma}_i^2} \left(\widehat{\beta}_i - \widehat{\beta}_{WFE}\right) \tag{5}$$

where $\widehat{\beta}_i$ is the pooled OLS estimator, $\widehat{\beta}_{WFE}$ is the weighted fixed effect pooled estimator, M_τ is an identity matrix, the $\tilde{\sigma}_i^2$ is the estimator of σ_i^2. The second step develops the standardised dispersion statistic as

$$\tilde{\Delta} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - k}{\sqrt{2k}}\right) \tag{6}$$

Under the null hypothesis with the condition of the normality of the error terms and of $(N, T) \longrightarrow \infty$ so long as $\sqrt{N}/T \longrightarrow \infty$, the $\tilde{\Delta}$ test has asymptotic standard normal distribution. The small sample properties of the dispersion tests can be improved under the normally distributed errors by considering the following mean and variance bias adjusted version:

$$\tilde{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - E(\tilde{z}_{it})}{\sqrt{var(\tilde{z}_{it})}}\right) \tag{7}$$

where the mean $E(\tilde{z}_{it}) = k$ and the variance $var(\tilde{z}_{it}) = 2k(T-k-1)/(T+1)$.

4.3 Panel causality test

The panel causality method depends on the existence of cross-section dependency and/or heterogeneity across countries or not. The bootstrap panel causality approach proposed by Kónya (2006) takes account for both cross-section dependence and region specific heterogeneity. This approach is connected with Seemingly Unrelated regression (SUR) estimation of the set of equations and the Wald tests with individual specific region bootstrap critical values. The bootstrap panel causality approach does not require any pre-testing for panel unit root test and cointegration analyses.
The system to be estimated in bootstrap panel causality approach can be written as:

$$\begin{cases} y_{1t} = \alpha_{1,1} + \sum_{i=1}^{ly1} \beta_{1,1,i} y_{1,t-i} + \sum_{i=1}^{lx1} \gamma_{1,1,i} x_{1,t-i} + \sum_{i=1}^{lz1} \delta_{1,1,i} z_{1,t-i} + \varepsilon_{1,1,t} \\ y_{2t} = \alpha_{2,1} + \sum_{i=1}^{ly2} \beta_{1,2,i} y_{2,t-i} + \sum_{i=1}^{lx2} \gamma_{1,2,i} x_{2,t-i} + \sum_{i=1}^{lz2} \delta_{1,2,i} z_{2,t-i} + \varepsilon_{1,2,t} \\ \dots \\ y_{Nt} = \alpha_{N,1} + \sum_{i=1}^{lyN} \beta_{1,N,i} y_{N,t-i} + \sum_{i=1}^{lxN} \gamma_{1,N,i} x_{N,t-i} + \sum_{i=1}^{lzN} \delta_{1,N,i} z_{N,t-i} + \varepsilon_{1,N,t} \end{cases} \tag{8}$$

and

$$\begin{cases} x_{1t} = \alpha_{1,1} + \sum_{i=1}^{ly1} \beta_{1,1,i} y_{1,t-i} + \sum_{i=1}^{lx1} \gamma_{1,1,i} x_{1,t-i} + \sum_{i=1}^{lz1} \delta_{1,1,i} z_{1,t-i} + \varepsilon_{1,1,t} \\ x_{2t} = \alpha_{2,1} + \sum_{i=1}^{ly2} \beta_{1,2,i} y_{2,t-i} + \sum_{i=1}^{lx2} \gamma_{1,2,i} x_{2,t-i} + \sum_{i=1}^{lz2} \delta_{1,2,i} z_{2,t-i} + \varepsilon_{1,2,t} \\ \dots \\ x_{Nt} = \alpha_{N,1} + \sum_{i=1}^{lyN} \beta_{1,N,i} y_{N,t-i} + \sum_{i=1}^{lxN} \gamma_{1,N,i} x_{N,t-i} + \sum_{i=1}^{lzN} \delta_{1,N,i} z_{N,t-i} + \varepsilon_{1,N,t} \end{cases} \tag{9}$$

and

$$\begin{cases} z_{1t} = \alpha_{1,1} + \sum_{i=1}^{ly1} \beta_{1,1,i} y_{1,t-i} + \sum_{i=1}^{lx1} \gamma_{1,1,i} x_{1,t-i} + \sum_{i=1}^{lz1} \delta_{1,1,i} z_{1,t-i} + \varepsilon_{1,1,t} \\ z_{2t} = \alpha_{2,1} + \sum_{i=1}^{ly2} \beta_{1,2,i} y_{2,t-i} + \sum_{i=1}^{lx2} \gamma_{1,2,i} x_{2,t-i} + \sum_{i=1}^{lz2} \delta_{1,2,i} z_{2,t-i} + \varepsilon_{1,2,t} \\ \dots \\ z_{Nt} = \alpha_{N,1} + \sum_{i=1}^{lyN} \beta_{1,N,i} y_{N,t-i} + \sum_{i=1}^{lxN} \gamma_{1,N,i} x_{N,t-i} + \sum_{i=1}^{lzN} \delta_{1,N,i} z_{N,t-i} + \varepsilon_{1,N,t} \end{cases} \tag{10}$$

where y denotes GDP, x indicates CO2 emissions, z refers to electricity consumption, l is the lag length and ε is the error term. For each system there are maximal lags for GDP, CO2 emissions and EC, which are the same across equations. The optimal joint lag represents the lag for which the Akaike Information Criterion (AIC) and Schwartz Bayesian Criterion (SBC) have minimal levels.

With respect to these systems, in country i there is one-way Granger causality running from x to y (z) if not all $\gamma_{1,i}$ are zero but all $\beta_{2,i}$ $(\delta_{2,i})$ are zero, there is one-way Granger causality from y (z) to x if not all $\gamma_{1,i}$ are zero but not all $\beta_{2,i}$ $(\delta_{2,i})$ are zero, there is two-way Granger causality between x and y (z) if neither all $\gamma_{1,i}$ nor all $\beta_{2,i}$ $(\delta_{2,i})$ are zero, and there is no Granger causality between x and y (z) if all $\gamma_{1,i}$ and $\beta_{i,l}$ $(\delta_{2,i})$ are zero.

5 Empirical results and discussion

To investigate the existence of cross-section dependence four different tests (LM, CDLM, CD and LM$_{adj}$) were carried out and the results are figured in Table 4. From Table 4, we conclude to strongly reject the null hypothesis of no cross-sectional dependence across the countries at the conventional levels of significance. This result implies that a shock occurred in one of the GCC countries seems to be transmitted to other countries.
Table 4 also present the result from the slope homogeneity tests of both standard F-test and Pesaran and Yamagata (2008). This test reject the null hypothesis of the slope homogeneity at conventional levels of significance. This result implies that a significant economic relationship in one country is not replicated in others.

Tests	**Statistic**	**p-value**
Breusch-Pagan LM	72.152	0.0000
Pesaran scaled CD$_{LM}$	10.434	0.0000
Pesaran CD	-1.5924	0.1113
LM$_{adj}$	5.395	0.0000
F test	67.605	0.0000
$\tilde{\Delta}$	5.744	0.0000
$\tilde{\Delta}_{adj}$	6.9041	0.0000

Table 4: Cross-section dependence and slope homogeneity test

The existence of the cross-sectional dependence and the heterogeneity across countries support evidence on the suitable of the bootstrap panel Granger causality technique[1]. The results from the bootstrap panel Granger causality approach[2] are reported in Table 5-10.

	Wald statistics	Bootstrap critical values			p-value
		1%	5%	10%	
KSA	0.8677	54.0312	19.2966	10.5909	0.5780
Bahrin	3.8904	48.9513	20.4303	11.8772	0.2950
Kuwait	0.0037	36.8648	16.3962	10.3780	0.9705
Oman	1.1167	33.5536	14.1044	8.9510	0.5265
UAE	0.7698	58.3849	20.7729	12.7278	0.6510
Qatar	0.3272	32.1987	12.4584	7.9906	0.7085

Table 5: GDP does not Granger cause CO2 emissions

The results for testing of the existence and direction of causality between GDP and CO2 emissions are reported in Table 5 and Table 6. The findings from these tables indicate the existence of reverse relationship from CO2 to economic growth for Bahrin and Kuwait and neither CO2 emissions nor economic growth is sensitive to KSA, Oman, UAE and Qatar. Regarding EC-CO2 emissions nexus (Table 7 and Table 8), evidence of bi-directional causality is found for United Arab Emirate. However a neutrality hypothesis holds for KSA, Bahrin, Kuwait, Oman and Qatar. Table 9 and Table 10 chow the results for the existence and direction of causality between economic growth and energy consumption. The founding from these tables indicate that there is a one-way Granger causality running from economic growth to energy consumption for United Arab Emirate and Qatar and two-way Granger causality for Bahrin.

[1] We refer to Kónya (2006) for the bootstrap procedure on how the country specific critical values are generated.
[2] The bootstrap critical values are obtained from 2000 replications.

	Wald statistics	Bootstrap critical values			p-value
		1%	5%	10%	
KSA	9.2376	17.9598	9.2979	5.8212	0.0525
Bahrin	45.2804***	17.0689	7.9938	5.2993	0.0010
Kuwait	17.1736**	22.6654	10.5497	6.9155	0.0210
Oman	1.4467	30.5152	11.9597	7.2038	0.4270
UAE	2.6415	20.4047	10.5887	7.2450	0.2830
Qatar	0.3777	39.2145	14.5371	9.1204	0.7135

Table 6: CO2 emissions does not Granger cause GDP
*** Indicates significance at the 0.01 level.
** Indicates significance at the 0.05 level.

	Wald statistics	Bootstrap critical values			p-value
		1%	5%	10%	
KSA	1.5898	47.3401	15.8178	9.8689	0.4625
Bahrin	0.2216	38.9070	16.7962	10.3804	0.7635
Kuwait	2.5606	45.0847	21.3876	12.3399	0.3610
Oman	0.0122	49.5036	18.8003	10.9199	0.9490
UAE	26.1235**	44.6559	18.1953	10.8859	0.0310
Qatar	0.3030	31.5138	13.1475	8.4505	0.7270

Table 7: EC does not Granger cause CO2 emissions
** Indicates significance at the 0.05 level.

	Wald statistics	Bootstrap critical values			p-value
		1%	5%	10%	
KSA	1.5898	39.4434	17.1727	9.9502	0.4665
Bahrin	0.2216	43.3605	17.6729	11.0455	0.7790
Kuwait	2.5606	43.8061	17.8104	10.1156	0.3475
Oman	0.0122	52.4955	18.7517	10.9793	0.9490
UAE	26.1235**	40.5722	16.2911	9.5155	0.0230
Qatar	0.3030	30.2514	12.2380	8.2618	0.7070

Table 8: CO2 emissions does not Granger cause EC
** Indicates significance at the 0.05 level.

	Wald statistics	Bootstrap critical values			p-value
		1%	5%	10%	
KSA	3.0529	23.4737	11.0565	6.8644	0.2715
Bahrin	8.7373*	33.6129	11.6254	7.0184	0.0750
Kuwait	7.1303	38.0847	15.8422	9.4208	0.1530
Oman	4.8534	32.2228	11.0604	7.5495	0.1750
UAE	9.5248*	26.3824	12.6931	8.6331	0.0835
Qatar	22.6300**	39.8778	16.9253	10.8804	0.0300

Table 9: GDP does not Granger cause EC
* Indicates significance at the 0.1 level.
** Indicates significance at the 0.05 level.

	Wald statistics	Bootstrap critical values			p-value
		1%	5%	10%	
KSA	5.4854	23.6812	12.8998	8.4993	0.1805
Bahrin	37.2401***	16.9934	7.9767	4.8938	0.0015
Kuwait	0.2624	24.8391	12.7950	8.3686	0.7495
Oman	1.1410	23.7842	10.6173	7.0731	0.4670
UAE	0.0231	20.7702	9.2216	6.0907	0.9130
Qatar	9.4741	35.0520	14.7435	9.1979	0.0975

Table 10: EC does not Granger cause GDP
** Indicates significance at the 0.05 level.

These results are partially consistent with Salahuddin and Gow (2014) and Jammazi and Aloui (2015).The results of this paper are contrary to those obtained by (Magazzino, 2016) who find a unidirectional causal link, running from energy use to the economic growth for Kuwait, Oman, and Qatar and a bi-directional relationship between economic growth and energy consumption for KSA.

The difference between the results for this paper can be attributed to differing time periods and methodology. In addition, in this work, the cross-sectional dependence is taken into account which considered of high importance for groups of countries with relations in terms of their economic policies.

6 Conclusions

This study re-examines causal link between economic growth, CO2 emissions and energy consumption in GCC countries for the period 2000-2011. We use the bootstrap panel causality approach, which take into account the cross-sectional dependence and heterogeneity across countries. The results suggest that the existence and direction of Granger causality differ among the different GCC countries.

In KSA, Kuwait and Oman, no evidence of causality running in any way between economic growth, CO2 emissions and energy consumption is found, thus supporting the neutrality hypothesis. With respect to Bahrin, bi-directional causality was found to exist between economic growth and energy consumption, thus supporting the feedback hypothesis. This result could be because of the fact that Bahrin's economic growth is still fairly dependent on electricity generation. There is no causal relationship between energy consumption and CO2 emissions. With respect to GDP-CO2 emissions nexus, there is a reverse causal relationship running from CO2 to GDP for Bahrin.

In terms of United Arab Emirate, no evidence of causality running in any way between economic growth and CO2 emissions is found. There is a bi-directional Granger causality between energy consumption and CO2 emissions. A unidirectional Granger causality running from economic growth to energy consumption is found for United Arab Emirate and Qatar, thus favouring the conservation hypothesis. This indicates that energy conservation policies have a little or no evidence affect on economic growth. This result may imply that electricity consumption is not sufficient to cause economic growth in UAE and Qatar.

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