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Energy Consumption, CO_2 Emissions and Economic Growth Nexus in Oman: Evidence from ARDL Approach to Cointegration and Causality Analysis

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Abstract

The paper examines the nexus between economic growth, energy consumption and carbon dioxide emission (CO_2) in Oman from 1980 to 2018. The study uses ARDL bounds, Johansen Cointegration and the Granger-causality tests. The bound test as well as the Johansen Cointegration test both reveals an existence of long-run relationship between CO_2 emissions and its determinants. This long relationship indicates that CO_2 in Oman is positively influenced by economic growth and energy consumption.

The analysis also suggested that in the short run; approximately 15.1 per cent of total disequilibrium in CO_2 emissions has being corrected each year. Moreover, Granger causality analysis indicated that there is a unidirectional causality running from each of the energy consumption (EC) and GDP per capita (economic growth) CO_2 emissions.

Based on the results obtained, the policy makers can formulate strict environmental and energy policies for the sake of reducing CO_2 emissions.

Keywords: Oman. CO2 emissions; economic growth; energy consumption; ARDL, Cointegration

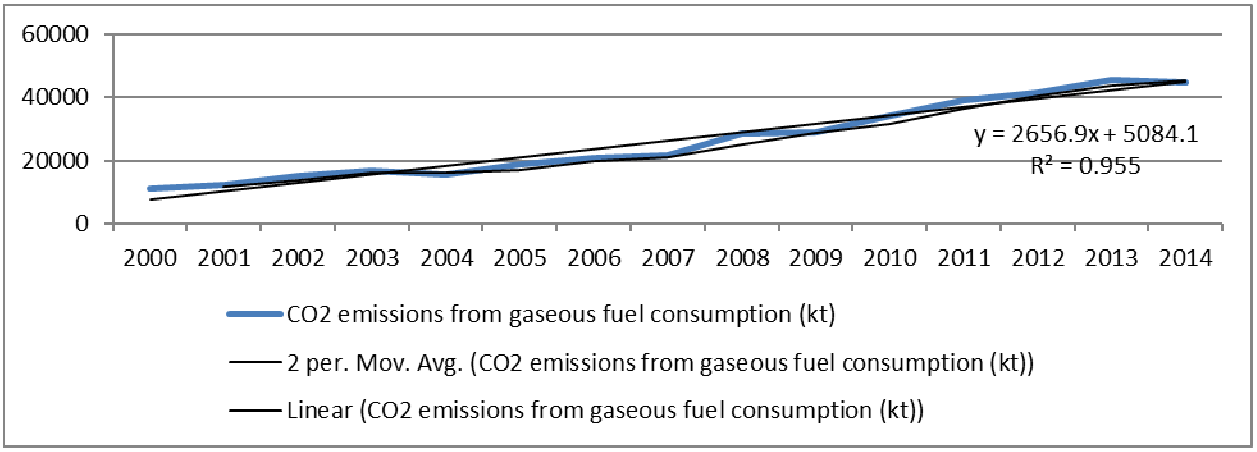
JEL Classification: C22; C32; Q43; Q56

1. Introduction

The relationship between energy consumption and economic growth has attracted the interests of researchers and policy makers in recent years. Increased demand for energy consumption has gown extensively due to rapid increases of economic activates, urbanization, and population growth. All these lead to increase of greenhouse emission and environmental deterioration. Therefore, achieving reasonable rates of economic growth and striking a delicate balance between sustained growth and environmental protection is one of the most significant development challenges faces the world today.

In case of Oman, as oil and natural gas sectors dominates the economy in terms of their big share in GDP and government revenues, They considered to be the primary cause of greenhouse gas (GHG) emissions within the country. So Oman is used to be vulnerable to impacts of increased average temperatures, less and more erratic precipitation, sea level rise (SLR) and desertification. According to study of WRI (2005)[1] the most contributing factor to CO2 in Oman, comes from gaseous fuels followed by liquid fuels, (see figure 1, below).

Figure 1: C02 emissions from gaseous fuel consumption (kt)

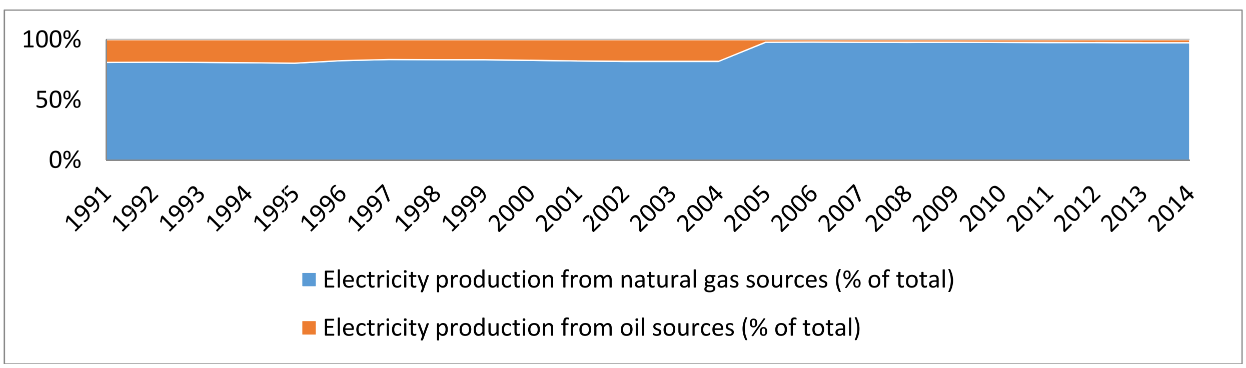


Source: World Bank, World Development Indicators, 2017

Another important factor for generating CO2 emissions comes from electricity and heat production. Electricity in Oman is generated from two sources, natural gas (97.5) and oil (2.5), figure 2.

Looking at the Sources of CO2 emissions which comes from energy sub-sectors in Oman (expressed as a percentage of the total Fuel combustion), electricity ranked number one followed by manufactured sector and transportation sector (figure 3)

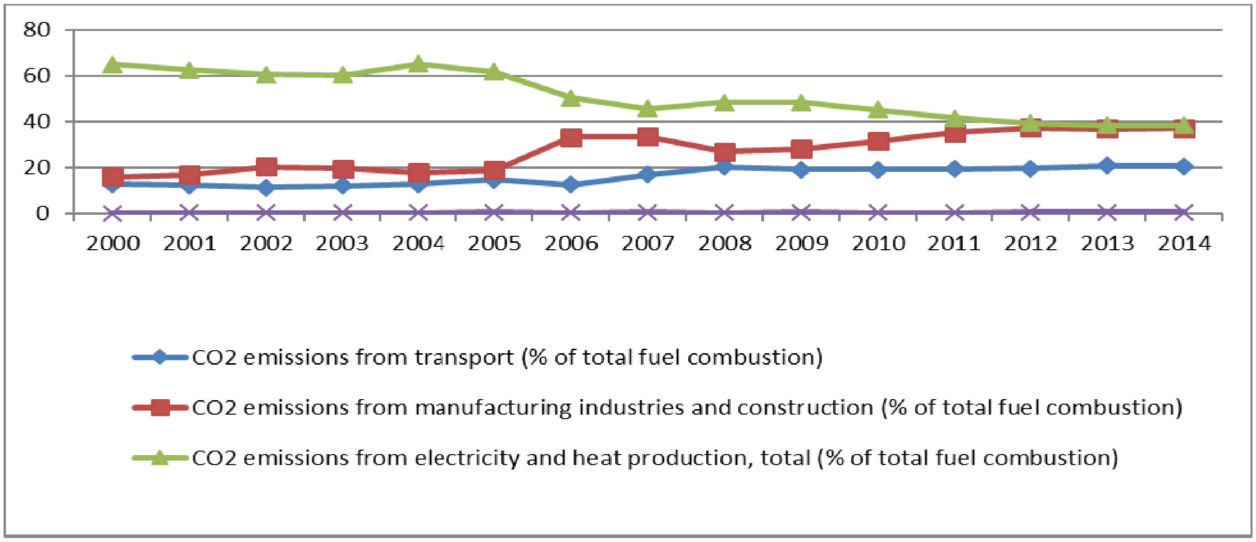
Figure 2: Electricity production as a percentage of fuel type in Oman, 1991–2014



Source: World Bank, World Development Indicators, 2017

[1] WRI (2005), Earth Trends Data Tables: Climate and Atmosphere, World Resources Institute, Washington, DC, available at: www.earthtrends.wri.org/

Figure 3: Sources of CO2 emissions from energy sub-sectors in Oman (expressed as a percentage of the total Fuel combustion)



Source: World Bank, World Development Indicators, 2017

2. Literature Review

In the existing literature, many studies have been conducted to test the relationship between energy consumption, CO2 emissions and economic.Below is a brief summary of the previous studies:

Squalli and Wilson (2006) tested the electricity consumption–income growth hypothesis for the six member countries of the GCC. They found support for the "feedback hypothesis" in Bahrain, Qatar, and Saudi Arabia; results of Kuwait and Oman are in line with the "conservation hypothesis"; while the "neutrality hypothesis" emerges for the United Arab Emirates.

James B. Ang. (2007). investigated the relationship between CO2 emissions, energy consumption and output in France and reported that there exists significant long run relationship among these variables. . The results provide evidence for the existence of a fairly robust long-run relationship between these variables for the period 1960–2000. The causality results support the argument that economic growth exerts a causal influence on growth of energy use and growth of pollution in the end. The results also point to a uni-directional causality running from growth of energy use to output growth in the short run.

Mehrara (2007) investigated the causal relationship between per capita energy consumption and per capita GDP in oil exporting countries. In his sample, seven MENA countries were examined (Algeria, Bahrain, Iran, Saudi Arabia, Oman, Kuwait, and United Arab Emirates (UAE)). He found strong unidirectional causality from economic growth to energy consumption. He suggests reforming energy prices in these countries without loss of economic growth and with an improvement of environmental quality

Sari and Soytas (2009) investigate the relationship between carbon emissions, income, energy and total employment in five selected OPEC countries (including two MENA countries: Algeria and Saudi Arabia) for the period 1971–2002. They mainly focus on the link between energy use and income. Employing the autoregressive distributed lag (ARDL) approach, they find that there is a cointegrating relationship between the variables in Saudi Arabia and conclude that none of the countries needs to sacrifice economic growth to decrease their emission levels

Soytas and Ramazan Sari (2009), investigates the long run Granger causality relationship between economic growth, carbon dioxide emissions and energy consumption in Turkey, controlling for gross fixed capital formation and labor. The most interesting result is that carbon emissions seem to Granger cause energy consumption, but the reverse is not true.

Ozturk and Acaravci (2010) examined the causal relationship between carbon dioxide emissions, energy consumption and economic growth using ARDL bounds testing approach of Cointegration and error-correction based Granger causality models for nineteen European countries for period 1960–2005. They found evidence of a long-run relationship between carbon emissions per capita, energy consumption per capita, real GDP per capita and the square of per capita real GDP only for Denmark, Germany, Greece, Iceland, Italy, Portugal and Switzerland. Despite that, there is a long-run unidirectional causal relationship in those countries.

Menyah and Wolde-Rufael (2010), the study explores the causal relationship between carbon dioxide (CO2) emissions, renewable, nuclear energy consumption, and real GDP for the US for the period 1960-2007. Using a modified version of the Granger causality test, they found a unidirectional causality running from nuclear energy consumption to CO2 emissions without feedback but no causality running from renewable energy to CO2 emissions.

Arouri et al. (2012) his work extends the recent findings of Liu (2005), Ang (2007), Apergis et al. (2009) and Payne (2010) by implementing recent bootstrap panel unit root tests and Cointegration techniques to investigate the relationship between carbon dioxide emissions, energy consumption, and real GDP for 12 Middle East and North African Countries (MENA) over the period 1981–2005. His results show that in the long-run energy consumption has a positive significant impact on CO2 emissions. More interestingly, he show that real GDP exhibits a quadratic relationship with CO2 emissions for the region as a whole. However, although the estimated long-run coefficients of income and its square satisfy the EKC hypothesis in most studied countries, the turning points are very low in some cases and very high in other cases, hence providing poor evidence in support of the EKC hypothesis. CO2 emission reductions per capita have been achieved in the MENA region, even while the region exhibited economic growth over the period 1981–2005.

Shahbaz, M., Feridun, M (2012), the study uses the Autoregressive Distributed Lag (ARDL) bounds testing procedure to identify the long run equilibrium relationship between electricity consumption and economic growth. Toda Yamamoto and Wald-test causality tests have identified the direction of the causal relationship between these two variables in the case of Pakistan in the period between 1971 and 2008. Ng-Perron and Clement-Montanes-Reyes unit root tests are used to handle the problem of integrating orders for variables. The results suggest that the two variables are in a long run equilibrium relationship and economic growth leads to electricity consumption and not vice versa.

Khan et al. (2013) explored the causal relationship between greenhouse emission, growth and energy consumption using Cointegration and Granger causality test in Pakistan during 1975–2011. Their findings reveal that energy consumption serves as an important driver of CO2 emissions and indicated unidirectional causality running from energy consumption to CO2 emissions.

Chindo Sulaiman (2014) The study investigate the relationship between energy consumption, carbon dioxide (CO2) emissions and economic growth in Nigeria using modified version of granger causality test suggested by Toda and Yamamoto. The empirical result of the causality test indicates unidirectional causality running from CO2 emissions to economic growth; energy consumption to CO2 emissions and bi-directional causality between energy consumption and economic growth. This suggests that any effort to lower the problem of CO2emissions by reducing energy consumption could negatively affect economic growth.

H. Hamdi, R. Sbia, and Muhammad S. (2014) examined the relationship between electricity consumption, foreign direct investment, capital and economic growth in the case of Bahrain over the period of 1980Q1–2010Q4. They used the ARDL bounds testing approach and found that Cointegration exists among the series. The VECM Granger causality analysis has exposed the feedback effect between electricity consumption and economic growth and the same is true for foreign direct investment and electricity consumption.

Salahuddin and Gow (2014) examined the empirical relationship among economic growth, energy consumption, and carbon dioxide emissions, in GCC countries. The results indicate 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. No significant relationship is found between economic growth and CO2 emissions

Omri et al. (2015), examines the relationship between financial development, CO2 emissions, trade and economic growth using simultaneous equation panel data models for a panel of 12 MENA countries over the period 1990 2011, find evidence which supports the existence of bidirectional causality between CO2 emissions and economic growth.

Li and Yang (2016) examined the dynamic impact of non-fossil energy consumption on carbon dioxide (CO2) emissions for the period 1965 and 2014 in China by using an autoregressive distributed lag model (ARDL). The results suggested that consumption of non-fossil energy plays a crucial role in curbing CO2 emissions in the long run but not in the short term. The results also suggested that, in both the long and short term, energy consumption and trade openness have a negative impact on the reduction of CO2 emissions, while GDP per capita increases CO2 emissions only in the short term. Finally, the Granger causality test indicates bidirectional causality between CO2 emissions and energy consumption.

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. The empirical evidence strongly supports the presence of unit roots. Cointegration tests reveal the existence of a clear long-run relationship only for Oman. Granger causality analysis shows that for three GCC countries (Kuwait, Oman, and Qatar) the predominance of the "growth hypothesis" emerges, since energy use drives the real GDP. Moreover, only for Saudi Arabia a clear long-run relation has not been discovered.

3. Methodology

3.1 Model Specification and Data

Following the empirical literature, we construct a model to test the relationship between energy consumption, CO2 and economic growth over the period 1980–2018.

$$InCO2t = \beta 0 + \Omega InYt + \Psi InECt + £t \tag{1}$$

Where CO_2 represents the carbon dioxide emissions metric ton per capita; Yt is the real GDP per capita (at constant price, 2011=$100 US) as a proxy for economic growth; ECt is energy consumption; β0 is constant term; $\Omega \; and \; \Psi$ are the coefficients of the model; and εt is the error term. The study used annual data over the period of 1980–2018. The world Development Indicators prepared by World Bank are the source of data to this study. All variables have been transformed into natural logarithms (ln) to help mobilize stationarity.

3.2 Cointegration Tests

$$LnCO2t = \gamma 0 + \sum_{i=1}^{k1} \gamma 1iLnCo2i\_1 + \sum_{i=0}^{k2} \gamma 2i\Delta LnECi\_1 + \sum_{i=0}^{k3} \gamma 3i\Delta LnYi\_1 + \theta 11LnCO2i\_1 + \theta 12LnECi\_1 + \theta 13LYi\_1 + \mu t \cdot \tag{2}$$

We examine the long-run relationship among the variables of interest employing the traditional Johansen Cointegration approach and the bounds-testing approach to Cointegration. Based on Equation (1), the ARDL-based approach to Cointegration can be written as follows:

Where Δ denotes the first difference of the selected variables while γ1i and ∅1i (i = 1, ... , 3) are the estimated parameters. ki (i = 1, ... , 3) are the optimal lag length determined by Akanke's information criterion (AIC), and £t t is an error term of white noise

The ARDL approach involves two steps. In the first step, the existence of the long-run relation between variables under investigation is tested by computing the F-statistics for testing the significance of the lagged levels of the variables in the error-correction form of the underling the ARDL model.

Pesaran et al (1996) tabulated two sets of appropriate critical values for different number of repressors (k), , and whether the model contains an intercept or trend or both. One set assumes that all the variables in the ARDL model are of 1(0), and another assumes all the variables are 1(1). If the F-statistic lies above the upper bound critical value for a given significance level, the conclusion is that there is a non-spurious long-run level relationship with the dependent variable. If the F-statistic lies below the lower bound critical value, the conclusion is that there is no long-run level relationship with the dependent variable. If it lies between the lower and the upper limits, the result is inconclusive. The general form of the null and alternative hypotheses for the F- statistic test is as follows:

H0: (φ1 = φ2 = … = φk = 0)

H1: (φ1 ≠ 0, = φ2 ≠ 0 . . . φk ≠ 0)

$$\Delta LnCO2t = \gamma 0 + \sum_{i=1}^{k1} \gamma 1 i Ln \Delta Co2i\_1 + \sum_{i=0}^{k2} \gamma 2 i \Delta LnECi\_1 + \sum_{i=0}^{k3} \gamma 3 i \Delta LnYi\_1 + \lambda ECt\_1 + \mu t \quad (3)$$

For the second step of analysis, one can estimate the long-run coefficient and make inference about their values. The estimate of the long-run coefficients may differ depending upon the model selection criteria used. In our case, the Schwarz Bayesian Criterion (SBC) is used. In this step, the resulting underlying ARDL equation is also verified with all its statistical diagnostic properties in order to get unbiased and consistent/efficient estimates. The test for serial correlation, functional form, normality and heteroscedasticity are carried out to ensure that the models are well specified and congruent with data. The error correction version of ARDL equation can then, be estimated in this stage. The adjustment parameter, as reflected in the coefficient of error correction term indicates the extent of adjustment of the dependent variable to the deviations from its long-run equilibrium value. The long run relationship among variables can be estimated after the selection of the ARDL model by AIC or SBC criterion. Once a long-run relationship has been established, a general error correction model (ECM) of equation (3) is formulated as follows:

3.3 .Causality Test

The ARDL bounds Cointegration approach proves the existence or absence of a long-term relationship between the variables included in the model but it does not indicate the direction of causality (Acaravci & Ozturk, 2010a). Thus, this article uses Granger procedure to examine the causal relationship between carbon dioxide emissions, energy consumption, and economic growth in Oman.

4. Empirical Results

4.1 Descriptive Statistics

The descriptive statistics, minimum, maximum, mean, standard deviation (Std. Dev.) and the coefficient of variation (CV) of these variables are recorded below in Table 1.

Over the period 1980–2018, the average of the ratio of the CO2 amounted approximately to 2.3 per cent with a coefficient of variation (CV) of 4.55. The energy consumption showed a highest fluctuation as indicated by the CV score.

Table 1: Summary Statistics for the Model Variables

Variables	Min.	Max.	Mean	Std. Dev.	Coefficient of Variations (VC)
Ln CO2t	1.49	3.028	2.258	0.497	4.545
LnYt	6.688	8.829	8.009	0.624	12.834
Ln ECt	9.201	9.875	9.690	0.155	62.516

Table 2 shows the correlation matrix. The correlation indicates a positive correlation between the CO2 emissions and all the other variables. Energy consumption shows strong positive correlation with CO2 emissions 90 percent followed by economic growth 65 percent.

Table 2: Correlation Matrix for the Model Variables

	LNCO2	LnEC	LnY
LNCO2	1		
LnEC	0.90	1	
LnY	0.65	0.81	1

4.2 Unit Root Test

The results of the test of the stationarity of the series of the model are reported in Table 3. The unit root (ADF) test showed that at level, all the series with the exception of Y are non-stationary (p-value > 0.05). The t statistics for ADF test for the CO2, EC are not greater than the critical values at 1 per cent, 5 per cent and 10 per cent levels, respectively, implying that the variables are non-stationary in their level forms.

On the other hand, Y is stationary at level. For the first difference, the ADF test showed that all variables are stationary with p-value less than 0.05. With the exception of Y, all the variables are integrated of order 1.

Table 3: Unit Root Test (ADF) for the Model Variables

Variables	Level Critical Values					First Difference Critical Values				
	1%	5%	10%	T-values	P-values	1%	5%	10%	T-values	P-values
LnCO2	-3.628	-2.946	-2.612	-0.453	0.889	-3.628	-3.628	-2.946	-7.950	0.000*
LnEC	-3.627	-2.946	-2.612	-1.729	0.408	-3.627	-2.946	-2.612	-3.978	0.040*
LnY	-3.616	-2.941	-2.609	-4.613	0.007*	-4.107	-2.943	-2.610	-4.107	0.003*

Lag order selection criterion is provided in Table 4. With the exception of SC that called for two lags, all the other criteria including AIC, HQ, final prediction error (FPE) and Sequential likelihood ratio (LR) called for three lags. Hence, lag three is considered as optimum lag in our model.

Table 4: VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	23.02299	NA	6.60e-05	-1.112388	-0.980428	-1.066331
1	124.4002	180.2262	3.91e-07	-6.244458	-5.716618*	-6.060227
2	128.8578	7.181681	5.09e-07	-5.992102	-5.068382	-5.669699
3	145.3521	23.82506*	3.46e-07*	-6.408450*	-5.088851	-5.947875*

Note: * indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.

4.3. Cointegration Test Results

The Cointegration test under the bounds testing approach involves comparing the F-statistics against critical values. Given that the value of the F-statistic is sensitive to the number of lags imposed each time on the differenced variables (Bahmani- Oskooee and Goswami,2003), we select the optimal order of lags of the model based on the Akaike Information (AIC) and the Schwarz–Bayesian(SBC) information criteria as suggested by Pesaran et al.(2001). The results of the lag selection criteria indicate that the optimal number of lags is one.

The calculated F-statistics, together with the critical values, are reported in Table 5. The computed F-statistic F (CO2 / EC Y) is 4.797, which is greater than the critical values of bounds. Hence, it is concluded that the null hypothesis is rejected, so there is a co-integration among variables.

Table 5: ARDL Bound Test for Cointegration

F-Statistics	4.797	
Significant Levels	Critical Values Bounds	
	Lower Critical Bounds (LCB) 1(0)	Lower Critical Bounds (LCB) 1(1)
10%	2.63	3.35
5%	3.1	3.87
2..5%	3.53	4.38
1%	4.13	4.78

4.4. Long run and Short Estimates of ARDL

Given the presence of a long-run relationship, the ARDL co-integration procedure was implemented to estimate Eq. (2) with maximum order of lag set to 1. The AIC criterion has been used to determine the coefficients of the level variables. As AIC is a good criterion, since it selects the smallest possible lag length and minimizes the loss of degree of freedoms as well the long-run results are reported in Table 6, where all estimated coefficients are statistically significant at 5% level of significance. The long-run estimates of energy consumption and economic growth of positively affect b per capita carbon emissions.

Table 6: Long-run Estimation Results (of CO2 Emissions

Variable	Coefficient	t-statistics	*p*-value
EC	0.809530	12.33706	{0.0000}
Y	0.218039	8.018617	{0.0000}
C	-8.9694	-5.145	{0.001}
R^2	0.822		
F	6.234		

Note: The asterisks *** is 5% significant level.

Table 7, report the short run dynamic estimates. The coefficients of estimated ECM are also negative and statistically significant at 5% confidence level. These values show that the whole system adjust at speed of 15% (the whole system can get back to long-run equilibrium at a speed of 15%). In other words, these values indicate that any deviation from the long-run equilibrium between variables is revised for every period to get back to the long-run equilibrium level.

Table 7: Short-run Estimation Results (of CO2 Emissions

Variable	Coefficient	t-statistics	*p*-value
ΔEC	0.081821	3.436712	{0.0015 }
ΔY	0.000710	0.000382	{0.0769}
ΔC	-8.9694	-5.145	{0.001}
ECM(-1)	-0.15260	-8.39944	{0.000}
R^2	0.8760		
F	8.6572		
D.W	2.027874		

Note: The asterisks *** is 5% significant level

4.5. Results of Johansen Cointegration Test

To determine if $LnC0_2$, LnEC, and LnY are cointegrated, we apply the Johansen multivariate Cointegration test. Before applying the test, we choose the optimum lag length, which may be used for the Johansen Cointegration test. Based on minimum AIC and SC through the estimation of the unconstrained VAR model for the first differences of the three variables under consideration, we obtain that the lag length is equal to one.. Since all variables are integrated of the same order, except GDP Per capita, Johansen Cointegration test is performed and results are given in Table 8. The result showed that the trace value exceeds the critical value and there are three Cointegration equation(s) at the 5 per cent significance level, while max eigenvalue indicates two Cointegration equations.

Table 8: Johansen Cointegration Test: Eviews 10 Output

Hypothesized		**Trace**	**0.05**		**Max-Eigen**	**0.05**	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**	Statistic	Critical Value	Prob.**
None *	0.686156	72.02229	29.79707	0.0000	41.71899	21.13162	0.0000
At most 1 *	0.404517	30.30331	15.49471	0.0002	18.66175	14.26460	0.0095
At most 2 *	0.276299	11.64155	3.841466	0.0006	11.64155	3.841466	0.0006

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level

4.6. Results of Granger-Causality Tests

Table 9 reveals the causality effect of the variables of interests adopted in this paper. The analysis shows that there is unidirectional causality running from energy consumption and from GDP Per capita to CO_2. This explains that, the major fluctuations in CO_2 in Oman are caused by these variables.

Table 9: Granger Causality Tests

Variables	**F-Stat.**	**p-value**	**Causality**
EC → CO_2	4.272	0.040	Yes
CO_2 → Ec	01536	0.6975	No
GDP-PC → CO_2	4.403	0.043	Yes
CO_2 → GDP-PC	0.867	0.358	No
GDP-PC → EC	4.251	0.047	Yes
EC → GDP-PC	O.009	0.923	No

4.7 Diagnostic and Stability Tests

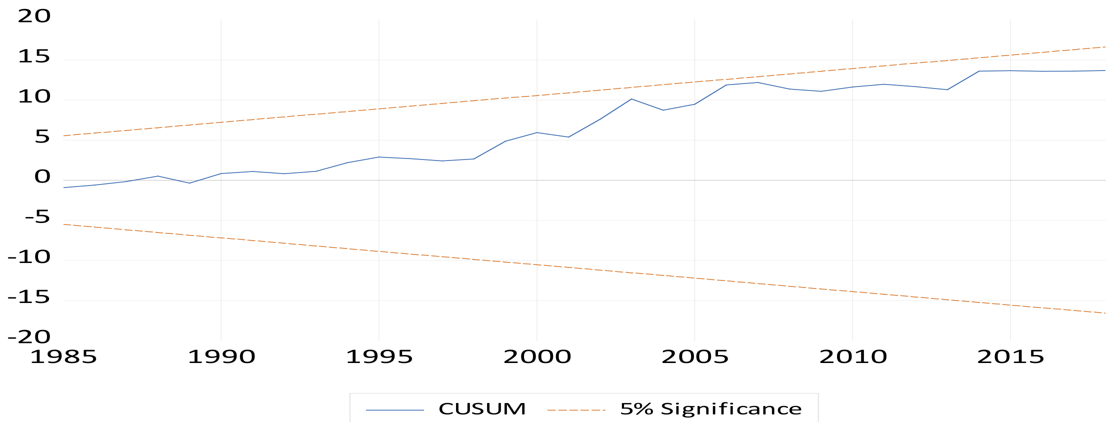
As reported in Table 10, the diagnostic tests of the ARDL model prove the absence of serial correlation (LM test), the absence of heteroscedasticity (ARCH test), and the normality of the residuals.

Table 10: ARDL – Model diagnostic test

Diagnostic test	**p-value**
Serial Correlation LM Test	0.9017
Heteroscedasticity Test	0.841
Normality Test	0.489
Heteroscedasticity Test: ARCH	0.1766

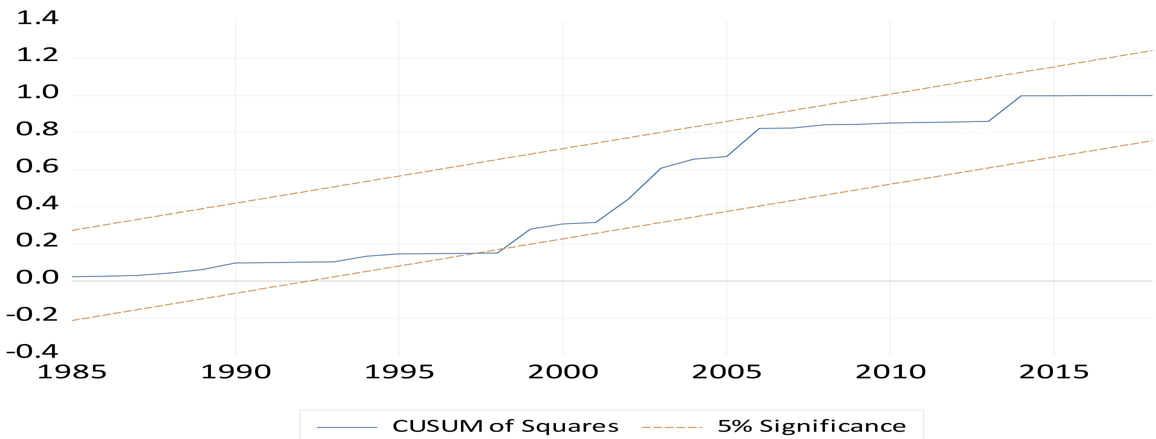
The stability of the model is evaluated using the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMSQ) of the recursive residual test for structural stability. A graphical representation of CUSUM AND CUSUMQ statistics are shown in fig.4 and fig.5. If the plot of the CUSUM and CUSUMSQ remains within the 5 per cent critical bound, the null hypothesis that all coefficients are stable cannot be rejected. As it is clear from Fig.4 and Fig.5, the plots of both the CUSUM and the CUSUMQ are within the boundaries and hence these statistics confirm the stability of the long run coefficients of the CO_2 Model.

Figure 4: Plot of CUSUM statistics for stability test



Note: The straight lines represent critical bounds at 5% significance level

Figure 5: Plots of CUSUMQ statistics for stability test



Note: The straight lines represent critical bounds at 5% significance level

5. Conclusion and Policy Implications

In the current paper, we empirically investigated the relationship between energy consumption, CO2 emissions, and economic growth in Oman during the period 1980–2018 by using ARDL bounds test of Cointegration, the Johansen Cointegration test, and the Granger-causality test

The empirical results show that there is a long-term Cointegration relationship between the three variables our results also show that the effect of economic growth and energy consumption on CO2 emissions is positive and statistically. The analysis also suggested that in the short run; approximately 15.1 per cent of total disequilibrium in CO2 emissions has being corrected each year. Moreover, Granger causality analysis indicated that there is a unidirectional causality running from each of the energy consumption (EC) and GDP per capita (economic growth) and CO2 emissions

The results have some policy implications for Oman. First, Oman should formulates strict environmental and energy policies in order to reduce CO_2 emissions.

Second, the government can adopt and encourage the use of renewable energy as best alternatives for oil and gaz.

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