UDK: 338.121:665.6/.7]:546.264-31:303.725.3(100)"1978/2017"
338.121:620.9]:546.264-31:303.725.3(100)"1978/2017"
Preliminary communication

THE RELATIONSHIP BETWEEN ECONOMIC GROWTH, OIL PRODUCTION, ENERGY CONSUMPTION AND CARBON DIOXIDE EMISSIONS: EVIDENCE FROM SELECTED OPEC COUNTRIES

Anh Tru Nguyen[1]

Abstract

The article aims to investigate the relationship between economic growth, oil production, energy consumption and CO_2 emissions in five OPEC countries for the last four decades (1978–2017). We found that per capita energy consumption has a negative relationship with per capita GDP while per capita CO_2 emissions positively affect per capita GDP. Per capita GDP negatively affects oil production, but per capita energy consumption has a positive relationship with oil production. Further, per capita CO_2 emissions have a positive relationship with oil production. Per capita energy consumption negatively influences per capita CO_2 emissions. We also found that there is a directional relationship running from per capita GDP to oil production, per capita energy consumption and per capita CO_2 emissions and from per capita CO_2 emissions to per capita energy consumption. The Johansen co-integration test shows that there is a long run relationship among variables. Our finding supports the conservation hypothesis that means the growth of GDP in these countries is found as a result of increasing energy consumption.

Keywords: *Economic Growth, Oil Production, Energy Consumption, Carbon Dioxide Emission, OPEC*

JEL classification: *O11, O47, Q43*

1. Introduction

The Organization of the Petroleum Exporting Countries (OPEC) have plentiful and rich energy resources and consequently, these countries have comparative advantages with many other countries due to existence of big reservoirs and potential energy resources (Abdoli et al., 2015). However, energy consumption is identified as a key source of global greenhouse emissions (Sari and Soytas, 2009). Energy consumption of the OPEC increased by 685 percent between 1970 and 2010 while

1 Faculty of Accounting and Business Management, Vietnam National University of Agriculture, Trau Quy, Gia Lam, Ha Noi, Viet Nam, E-mail: nguyenanhtru@vnua.edu.vn

carbon dioxide (CO_2) emissions increased by 440 percent in the same period due to booming fossil fuels (Adetutu, 2014). By 2010, the OPEC contributed 7 percent to CO_2 emissions in the global and energy use has been defined as the main source of greenhouse emissions in these countries (Chiroma et al., 2015). Three countries, namely Saudi Arabia, the United Arab Emirates (UAE) and Qatar have been defined as the largest per capita CO_2 emitter in the world (Hertog and Luciani, 2009).

There is the fact that the oil shocks affect the oil producing countries more than the oil importing countries. For example, Saudi Arabia concerns about the growth of domestic petroleum consumption because it reduces the quantity of oil exports which is an important contributor to government spending and employment (Onoh et al., 2018).

What is the relationship between economic growth, oil production, energy consumption and CO_2 emissions in OPEC countries? How do these variables correlate in the short run and long run? The main contribution of the research to the existing literature is to investigate the causal relationship between economic growth, oil production, energy consumption and CO_2 emissions of five selected OPEC countries, namely the Islamic Republic of Iran, Iraq, Kuwait, Saudi Arabia, and the UAE for the last four decades (1978–2017) using the vector autoregressive (VAR) model. More importantly, policies are recommended to the governments of these countries in order to foster economic growth, reduce emissions and achieve sustainable development.

The rest of this paper is organized as follows. Section 2 presents the empirical review. Research methods are discussed in Section 3. In Section 4 we present results and discussion. Finally, conclusion and policy implications are summarized in Section 5.

2. Empirical Review

The relationship between economic growth, oil production, energy consumption and CO_2 emissions is strongly debated by scholars over the recent years. Arouri et al. (2012) examined the relationship between CO_2 emissions, energy consumption and real gross domestic product (GDP) for 12 Middle East and North African countries (MENA) between 1981 and 2005. They found that although the estimated long-run coefficients of income and its square satisfy the Environmental Kuznets Curve (EKC) hypothesis in most studied countries, the turning points are very low in some cases and very high in other cases and therefore it shows poor evidence in support of the EKC hypothesis. Likewise, Magazzino (2016) investigated the nexus between CO_2 emissions, economic growth and energy use for 10 Middle East countries from 1971 to 2006. He claimed that the growth hypothesis holds for the Gulf Cooperation Council (GCC) while in four non-GCC countries forecast errors in energy use are mainly due to energy use itself, and the forecast errors in economic growth are correlated to real GDP itself. A research by Kivyiro and Arminen (2014) assessed the links between CO_2 emissions, energy consumption, economic development and foreign direct investment (FDI) in six Sub Saharan African countries. Results showed that unidirectional Granger causality relationships run from other variables to CO2 emissions, and from GDP to FDI. Granger causality running to CO2 emissions more frequently exists in countries where the evidence supports the EKC hypothesis. Similarly, Khobai and Roux (2017) examined the relationship between energy consumption, CO_2 emission, economic growth, trade openness and urbanization in South Africa for the period 1971–2013. They concluded that there is a long run relationship between energy consumption, CO_2 emission, economic growth, trade openness and urbanization in this country. In addition, there is a unidirectional causality running from CO_2 emissions, economic growth, trade openness and urbanization to energy consumption and from energy consumption, CO_2 emissions, trade openness and urbanization to economic growth.

Further, a study by Salahuddin and Khan (2013) explored the causal relationship between economic growth, energy consumption and CO_2 emission in Australia between 1965 and 2007. Results addressed that there is no cointegrating relationship among the variables. There is a bi-directional relationship running from energy consumption to economic growth while there is no relationship between CO_2 emission and economic growth. Likewise, Peng et al. (2016) examined the causal link between economic growth, FDI and CO_2 emissions in China. They found that there is a directional relationship running from GDP to FDI and vice versa. GDP is caused by CO_2 emissions in Neimenggu, Hubei, Guangxi and Gansu while there is bidirectional causality between these two variables in Shanxi. Begum et al. (2015) assessed the impact of GDP growth, energy consumption and population growth on CO_2 emissions in Malaysia from 1970 to 1980. Results indicated that the hypothesis of the EKC is not valid in this country during the study period. Both per capita energy consumption and per capita GDP positively affect CO_2 emissions, but population growth rate has no significant effects on per capita CO_2 emission.

Moreover, Salahuddin and Gow (2014) examined the relationship between economic growth, energy consumption and CO_2 emissions in the Gulf Cooperation Council countries for the period 1980–2012. They found that there are positive relationships between energy consumption and CO_2 emissions and between economic growth and energy consumption in the short run and long run. Lastly, Alshehry and Belloumi (2015) investigated the relationship between energy consumption, energy price, CO_2 emissions and economic growth in Saudi Arabia between 1975 and 2010. Results showed that there is a long-run relationship between these variables. In addition, a long-run unidirectional causality running from energy consumption to economic growth and CO_2 emissions, bidirectional causality between carbon dioxide emissions and economic growth, and a long-run unidirectional causality running from energy price to economic growth and CO_2 emissions.

3. Methodology

3.1 Data and Sources

A panel dataset for the relationship between economic growth, energy consumption and CO_2 emissions in the OPEC countries is gathered from the World Development Indicators released by the World Bank. The quantity of oil production is collected from the BP Statistical Review. Specifically, a panel dataset is collected in five selected OPEC countries, including the Islamic Republic of Iran, Iraq, Kuwait, Saudi Arabia, and the UAE, between 1978 and 2017. Thus, a total of 200 observations is entered for data analysis. The panel data is used for this research because of the following advantages: (1) it benefits in terms of obtaining a large sample, giving more degree of freedom, more information and less multi-collinearity among variables; and (2) it may overcome constraints related to control individual or time heterogeneity faced by the cross-sectional data (Hsiao, 2014).

3.2 The Vector Autoregressive (VAR) Model

The VAR model is employed to examine the causality between economic growth, oil production, energy consumption and CO_2 emissions in five selected OPEC countries for the period 1978–2017. The VAR model is chosen for this study because it interprets the endogenous variables solely by their own history, apart from deterministic regressors and therefore this method incorporates non-statistical a priori information (Pfaff, 2008).

The specification of a VAR model can be defined as follows (Pfaff, 2008):

$$Y_t = A_1 Y_{(t-1)} + \ldots + A_p Y_{(t-p)} + \varepsilon_t \quad (i)$$

Where: Y_t denotes a set of K endogenous variables such as per capita GDP, oil production, per capita energy consumption, and per capita CO_2 emissions; A_i represents (K x K) coefficient matrices for i = 1,…, p; and $\mathcal{E}_t$ is a K-dimensional process with $E(\mathcal{E}_t) = 0$.

An important characteristic of the VAR model is stability and therefore it generates stationary time series with time invariant means, variances and covariance structure, given sufficient starting values. The stability of an empirical VAR model can be analyzed by considering the companion form and computing the eigenvalues of the coefficient matrix. A VAR model may be specified as follows (Pfaff, 2008):

$$\varepsilon_t = A\varepsilon_{(t-1)} + V_t \quad (ii)$$

Where: ε_t denotes the dimension of the stacked vector; A is the dimension of the matrix (K_p x K_p); and V_t represents (KP x 1).

Table 1. Description of Covariates in the VAR Model

Variables	Unit
Per Capita GDP	US$
Oil Production	Tonne
Per Capita Energy Consumption	Kg of Oil
Per Capita CO_2 Emissions	Metric Tonne

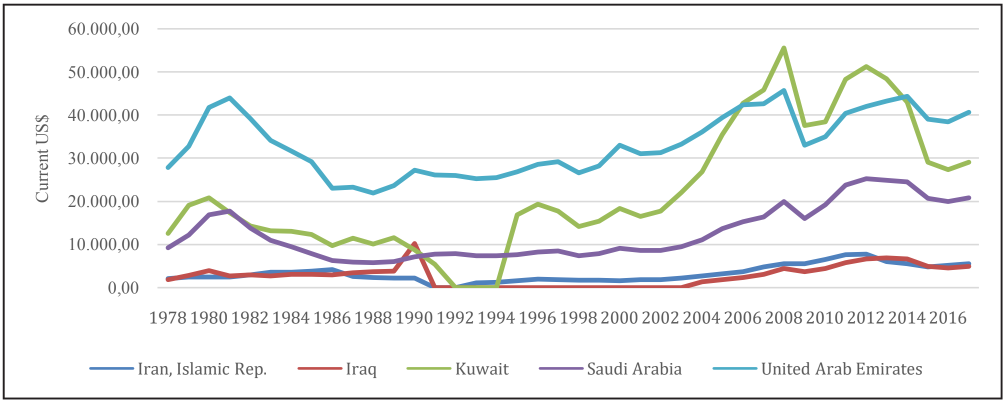
Source: Author, 2019
Note: US$ means United States Dollar

In this research, the procedure of a VAR Model includes six steps, consisting of (1) performing the unit root test; (2) determining lag length; (3) estimating the VAR Model; (4) testing the Granger causality; (5) checking the stability of eigenvalues; and (6) implementing the Johansen test for co-integration. The VAR Model is estimated by the Stata MP 14.2 software.

4. Results and Discussion

4.1 Characteristics of economic growth, oil production, energy consumption and CO2 emissions in selected OPEC countries: An overview

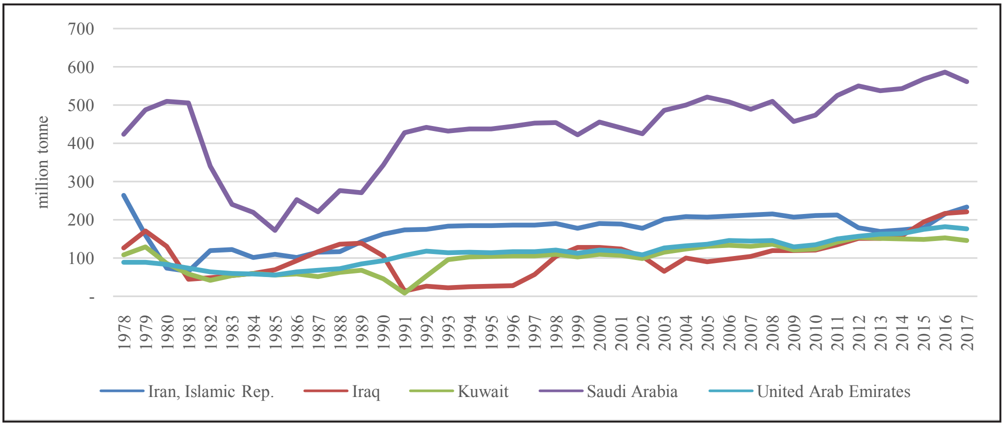
Graph 1. Per Capita GDP of Selected OPEC Countries



Source: World Bank, 2019

Per capita GDP of five countries increased between 1978 and 2017. Per capita GDP is dominated by the UAE, followed by Kuwait, while Iraq had the lowest per capita GDP. For instance, by 2017, per capita GDP of the UAE reached more than US$40,000 which was doubled higher than that of Saudi Arabia and about five times higher than that of Iraq in the same period (Graph 1).

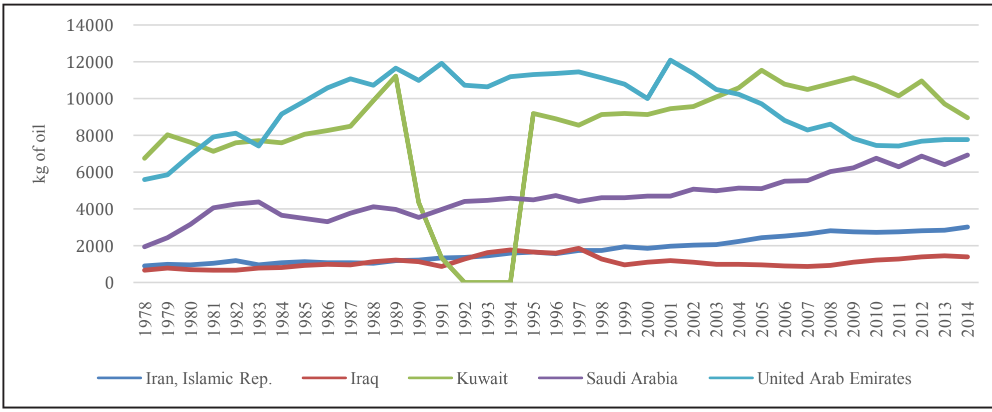
Graph 2. Quantity of Oil Production of Selected OPEC Countries



Source: World Bank, 2019

For four decades (1978–2017), Saudi Arabia was the leading country in oil production followed by the Islamic Republic of Iran while Iraq had the lowest quantity of oil production. Oil production of Saudi Arabia significantly increased from 1985 onward and by 2017, oil production of this country accounted for 562 million tonnes which was higher than that of Kuwait by 3.8 times and the UAE by more than 3 times (Graph 2).

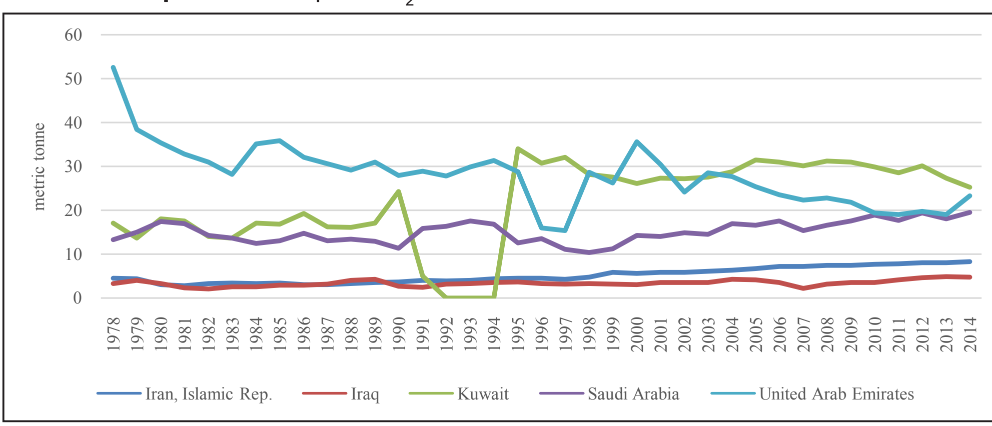
Graph 3. Per Capita Energy Consumption of Selected OPEC Countries



Source: World Bank, 2019

From 1980 to 2003, the UAE had the largest per capita energy consumption, but from 2003 onward Kuwait has overcome the UAE to become the largest energy consumer. By 2014, Kuwait consumed nearly 9,000 kg of oil per capita which was nearly three times higher than that of the Islamic Republic of Iran and more than six times higher than that of Iraq (Graph 3).

Graph 4. Per Capita CO_2 Emissions of Selected OPEC Countries



Source: World Bank, 2019

For the period 1978–1994, per capita CO_2 emissions was dominated by the UAE, but from 1995 onward, Kuwait has overcome the UAE to become the highest CO_2 emitter. By 2014, per capita CO_2 of Kuwait accounted for more than 25 metric tonnes which was 3 times higher than that of the Islamic Republic of Iran and 5.3 times compared to that of Iraq (Graph 4).

Table 2. Characteristics of Economic Growth, Oil Production, Energy Consumption and CO_2 Emissions of Selected OPEC Countries

Variable	Mean	SD	Min	Max
Per Capita GDP	14901.24	14165.08	0	55572
Oil Production	185.32	141.13	9.2	586.6
Per Capita Energy Consumption	4680.44	3863.93	0	12087.1
Per Capita CO_2 Emissions	13.62	11.21	0	52.6

Source: Author's calculation, 2019
Note: SD denotes standard deviation

The average per capita GDP and oil production of five OPEC countries account for nearly US$15,000 and 186 million tonnes, respectively. Per capita energy consumption and CO_2 emissions account for 4,680 kg of oil and more than 13 metric tonnes, respectively, on average (Table 2).

4.2 The relationship between economic growth, oil production, energy consumption and CO_2 emissions in selected OPEC countries

4.2.1 Implementation of the Unit Root Test

The unit root test is carried out to check the stationarity of the time series variables (Adeola and Ikpesu, 2016). In this research, the Augmented Dickey-Fuller (ADF) test is used to examine the stationarity of per capita GDP, oil production, per capita energy consumption and per capita CO_2 emissions with the hypothesis as follows:

Null hypothesis (H_0): The variables contain a unit root
Alternative hypothesis (H_a): The variables do not contain a unit root

Table 3. The ADF Test for the Unit Root

	Level		1st Difference	
	T-statistics	P-value	T-statistics	P-value
LnPer Capita GDP	-3.708***	0.004	-3.830***	0.002
LnOil Production	-3.331**	0.013	-3.223**	0.018
LnPer Capita Energy Consumption	-5.530***	0.000	-6.345***	0.000
LnPer Capita CO_2 Emissions	-4.367***	0.000	-4.597***	0.000

Source: Author's calculation, 2019

Results show that we cannot reject the null hypothesis, and this implies that all variables are integrated at the level (Table 3).

4.2.2 Determination of the Lag Length

The purpose of this step is to specify the optimal lag for the VAR Model. If the lag is used too little, then the residual of the regression will not show the white noise process and as the result, the actual error could not be accurately estimated by the model (Suharsono et al., 2017).

Table 4. Selection of the Lag Length

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-1267.67				5.077	12.976	13.003	13.043
1	-738.78	1057.8	16	0.000	0.027	7.742	7.878*	8.077*
2	-721.74	34.09	16	0.005	0.026*	7.732*	7.975	8.334
3	-708.77	25.93	16	0.055	0.027	7.763	8.115	8.632
4	-690.33	36.87*	16	0.002	0.027	7.738	8.198	8.875

Endogenous: LnPer capita GDP LnOil production LnPer capita energy consumption LnPer capita CO_2 emissions

Exogenous: Constant

Number of observations = 196

Source: Author's calculation, 2019

*Notes: *denotes lag order selected by the criterion; LL means log likelihood values; LR represents sequential modified LR test statistics; FPE denotes final prediction error; AIC means Akaike information criterion; HQIC represents Hannan-Quinn information criterion; and SBIC means Schwarz's Bayesian information criterion.*

As seen in Table 4, results suggest that the optimal lag length in this case is two lags because this value is recommended by AIC indicator. Therefore, two lags (the number of lag is equal to 2) is chosen to run the VAR Model in the next step.

4.2.3 Estimation of the VAR Model

We found that per capita energy consumption has a negative relationship with per capita GDP while per capita CO_2 emissions positively affect per capita GDP. Per capita GDP negatively affects oil production, but per capita energy consumption has a positive relationship with oil production. Further, per capita CO_2 emissions have a positive relationship with oil production. Lastly, per capita energy consumption negatively influences per capita CO_2 emissions (see details in Table 5 of the Appendices).

4.2.4 Testing the Granger Causality

The goal of this step is to assess the predictive capacity of a single variable on other variables (Musunuru, 2017). In this study, hypotheses need to be tested as follows:

Testing the relationship between per capita GDP and other variables:

Null hypothesis (H_0): Per capita GDP does not cause oil production, per capita energy consumption and per capita CO_2 emissions

Alternative hypothesis (H_a): Per capita GDP causes oil production, per capita energy consumption and per capita CO_2 emissions

Testing the relationship between oil production and other variables:

Null hypothesis (H_0): Oil production does not cause per capita GDP, per capita energy consumption and per capita CO_2 emissions

Alternative hypothesis (H_a): Oil production causes per capita GDP, per capita energy consumption and per capita CO_2 emissions

Testing the relationship between per capita energy consumption and other variables:

Null hypothesis (H_0): Per capita energy consumption does not cause per capita GDP, oil production and per capita CO_2 emissions

Alternative hypothesis (H_a): Per capita energy consumption causes per capita GDP, oil production and per capita CO_2 emissions

Testing the relationship between per capita CO_2 emissions and other variables:

Null hypothesis (H_0): Per capita CO_2 emissions do not cause per capita GDP, oil production and per capita energy consumption

Alternative hypothesis (H_a): Per capita CO_2 emissions cause per capita GDP, oil production and per capita energy consumption

Table 6. Results of the Granger Causality Wald Test

Directional Relationship	Probability	Conclusion
Per capita GDP → Oil production	0.04 < 0.05	Reject H_0
Per capita GDP → Per capita energy consumption	0.00 < 0.05	Reject H_0
Per capita GDP → Per capita CO_2 emissions	0.00 < 0.05	Reject H_0
Oil production → Per capita GDP	0.10 > 0.05	Accept H_0
Oil production → Per capita energy consumption	0.16 > 0.05	Accept H_0
Oil production → Per capita CO_2 emissions	0.13 > 0.05	Accept H_0
Per capita energy consumption → Per capita GDP	0.59 > 0.05	Accept H_0
Per capita energy consumption → Oil production	0.59 > 0.05	Accept H_0
Per capita energy consumption → Per capita CO_2 emissions	0.17 > 0.05	Accept H_0
Per capita CO_2 emissions → Per capita GDP	0.62 > 0.05	Accept H_0
Per capita CO_2 emissions → Oil production	0.37 > 0.05	Accept H_0
Per capita CO_2 emissions → Per capita energy consumption	0.00 < 0.05	Reject H_0

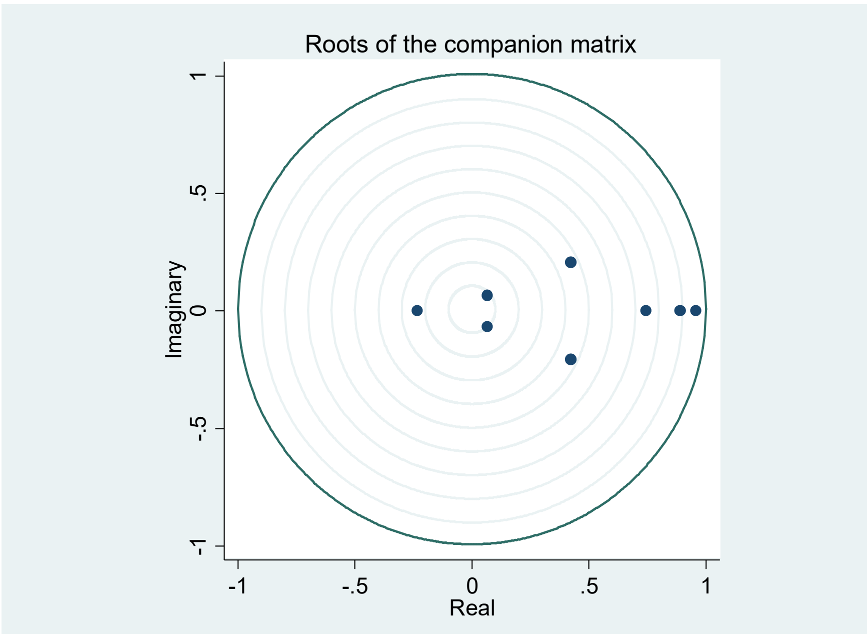
Source: Author's calculation, 2019

We found that there is a directional relationship running from per capita GDP to oil production, per capita energy consumption and per capita CO_2 emissions and from per capita CO_2 emissions to per capita energy consumption (Table 6).

4.2.5 Examination of Eigenvalue Stability

The objective of this step is to examine stability of the eigenvalues in the VAR Model. All the eigenvalues lie inside the unit circle and we can conclude that the VAR Model satisfies stability condition (Graph 5).

Graph 5. Checking Eigenvalue Stability



Source: Author's calculation, 2019

4.2.6 Performance of the Johansen Co-integration Test

The Johansen co-integration test is performed to examine the long run relationship among variables. If variables are co-integrated, it suggests that there is a long term relationship among variables (Musunuru, 2017).

The hypothesis to be tested can be identified as follows:

Null hypothesis (H_0): There is no co-integration among variables

Alternative hypothesis (H_a): There is co-integration among variables

In this study, the Johansen co-integration test is performed by trace statistic test. Trace statistic test is a likelihood-ratio-type test, which operates under different assumptions in the deterministic part of the data generation process (Lutkepohl et al., 2001).

Table 7. Results of Trace Statistic in the Johansen Co-integration Test

Maximum rank	LL	Eigenvalue	Trace Statistic	5% Critical Value	1% Critical Value
0	-770.99		81.28	47.21	54.46
1	-749.90	0.191	39.12	29.68	35.65
2	-737.63	0.116	14.57*1*5	15.41	20.04
3	-732.48	0.050	4.27	3.76	6.65
4	-730.34	0.021			

Source: Author's calculation, 2019

*Notes: *1 and *5 denote the number of co-integrations (ranks) chosen to accept the null hypothesis at 1% and 5% critical values, respectively*

As seen in Table 7, we cannot reject the null hypothesis in the rank two (two co-integrations) because trace statistic is less than the 5% and 1% critical values (14.57 < 15.41 and 14.57 < 20.04) and this implies that there are two co-integrations among variables at the 1% and 5%, respectively.

4.3 Discussion

We found that per capita energy consumption has a negative relationship with per capita GDP while per capita CO_2 emissions positively affect per capita GDP. This result reflects that per capita GDP of five OPEC countries relies on oil exports and therefore if the domestic consumption of energy increases, then per capita GDP tends to decrease. Per capita GDP negatively affects oil production, but per capita energy consumption has a positive relationship with oil production and this suggests that the growth of oil production is response to not only oil exports but also the demand for domestic energy consumption. Further, per capita CO_2 emissions have a positive relationship with oil production. Per capita energy consumption negatively influences per capita CO_2 emissions. Oil exploitation in five OPEC countries should be controlled because it is found as a driver contributing to CO_2 emissions in the region. We also found that there is a directional relationship running from per capita GDP to oil production, per capita energy consumption and per capita CO_2 emissions and from per capita CO_2 emissions to per capita energy consumption. The Johansen co-integration test shows that there is a long run relationship among variables.

Our results are consistent with Saidi et al. (2017) who found that there is a causal relationship running from GDP to CO_2 emissions in five selected OPEC countries, namely Algeria, Nigeria, Indonesia, Saudi Arabia and Venezuela, between 1990 and 2014. Moreover, similar to the argument of Salahuddin and Gow (2014), we found no significant relationship between economic growth and CO_2 emissions. Magazzino (2016) concluded that there is unidirectional causality running from energy consumption to economic growth in 10 Middle East countries for the period 1971–2006. Therefore, his study supports the growth hypothesis which implies that an increase in energy consumption may contribute to growth process. However, unlike Magazzino (2016), we found that there is a causal relationship running from per capita GDP to per capita energy consumption in five OPEC countries and this supports the conservation hypothesis which occurs if an increase in GDP causes an increase in energy consumption.

5. Conclusion and Policy Implications

The aim of this article is to examine the relationship between economic growth, oil production, energy consumption and CO_2 emissions in five OPEC countries for the period 1978–2017. We found that per capita energy consumption has a negative relationship with per capita GDP while per capita CO_2 emissions positively affect per capita GDP. Per capita GDP negatively affects oil production, but per capita energy consumption has a positive relationship with oil production. Further, per capita CO_2 emissions have a positive relationship with oil production. Per capita energy consumption negatively influences per capita CO_2 emissions. We also found that there is a directional relationship running from per capita GDP to oil production, per capita energy consumption and per capita CO_2 emissions and from per capita CO_2 emissions to per capita energy consumption. The Johansen co-integration test shows that there is a long run relationship among variables.

Energy policies should be recommended to five OPEC countries in order to facilitate economic growth, reduce CO_2 emissions and achieve a sustainable development. First, oil exploitation needs to be effectively managed since it is defined as a driver leading to increasing CO_2 emissions in the region. Second, our results support the conservation hypothesis, and this implies that the growth of GDP is the result of increasing energy consumption. That means in order to foster the economy, oil production of five OPEC countries needs to meet a twin demand at the same time, including domestic and export demands for oil. Finally, heavy dependence on oil may generate an unsustainable development for these countries because oil is a fossil fuel energy which significantly decreases in reserve in recent decades. Thus, advanced technologies in oil production and alternative energy sources such as solar, wind and wave energy should be encouraged in the near future.

References

Abdoli, G., Farahani, Y. G., and Dastan, S. (2015) "Electricity Consumption and Economic Growth in OPEC Countries: A Cointegrated Panel Analysis". *OPEC Energy Review*, 39(1), pp. 1-16.

Adeola, O., and Ikpesu, F. (2016) "An Empirical Investigation of the Impact of Bank Lending on Agricultural Output in Nigeria: A Vector Autoregressive (VAR) Approach". *The Journal of Developing Areas*, 50(6), pp. 89-103.

Adetutu, M. O. (2014) "Energy Efficiency and Capital-Energy Substitutability: Evidence from Four OPEC Countries". *Applied Energy*, 119, pp. 363-370.

Alshehry, A. S., and Belloumi, M. (2015) “Energy Consumption, Carbon Dioxide Emissions and Economic Growth: The Case of Saudi Arabia”. *Renewable and Sustainable Energy Reviews*, 41, pp. 237-247.

Arouri, M. E. H., Youssef, A. B., M’henni, H., and Rault, C. (2012) “Energy Consumption, Economic Growth and CO_2 Emissions in Middle East and North African Countries”. *Energy Policy*, 45, pp. 342-349.

Begum, R. A., Sohag, K., Abdullah, S. M. S., and Jaafar, M. (2015) “CO_2 Emissions, Energy Consumption, Economic and Population Growth in Malaysia”. *Renewable and Sustainable Energy Reviews*, 41, pp. 594-601.

BP (2019). Statistical Review of World Energy. [Online] Available at https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html. Accessed 20 June 2019.

Chiroma, H., Abdul-Kareem, S., Khan, A., Nawi, N. M., Gital, A. Y. U., Shuib, L., ..., and Herawan, T. (2015) “Global Warming: Predicting OPEC Carbon Dioxide Emissions from Petroleum Consumption Using Neural Network and Hybrid Cuckoo Search Algorithm”. *Plos One*, 10(8), pp. 1-21. DOI: 10.1371/journal.pone.0136140.

Hertog, S., and Luciani, G. (2009) “Energy and Sustainability Policies in the GCC”. Discussion Paper No 6. Kuwait Programme on Development, Governance and Globalisation in the Gulf States. The Centre for the Study of Global Governance, 2009.

Hsiao, C. (2014) “*Analysis of Panel Data”*. Third Edition, Cambridge University Press, New York.

Khobai, H. B., and Roux, P. L. (2017) “The Relationship between Energy Consumption, Economic Growth and Carbon Dioxide Emission: The Case of South Africa”. *International Journal of Energy Economics and Policy*, 7(3), pp. 102-109.

Kivyiro, P., and Arminen, H. (2014) “Carbon Dioxide Emissions, Energy Consumption, Economic Growth, and Foreign Direct Investment: Causality Analysis for Sub-Saharan Africa”. *Energy*, 74, pp. 595-606.

Lütkepohl, H., Saikkonen, P., and Trenkler, C. (2001) “Maximum Eigenvalue versus Trace Tests for the Cointegrating Rank of a VAR Process”. *The Econometrics Journal*, 4(2), pp. 287-310.

Magazzino, C. (2016) “CO_2 Emissions, Economic Growth, and Energy Use in the Middle East Countries: A Panel VAR Approach”. *Energy Sources, Part B: Economics, Planning, and Policy*, 11(10), pp. 960-968. DOI: 10.1080/15567249.2014.940092.

Musunuru, N. (2017) “Causal Relationships between Grain, Meat Prices and Exchange Rates”. *International Journal of Food and Agricultural Economics*, 5(4), pp. 1-10.

Onoh, J. O., Nwachukwu, T., and Mbanasor, C. A. (2018) "Economic Growth in OPEC Member States: Oil Export Earnings versus Non-oil Export Earnings". *Journal of Developing Country Studies*, 8(2), pp. 77-94.

Peng, H., Tan, X., Li, Y., and Hu, L. (2016) "Economic Growth, Foreign Direct Investment and CO_2 Emissions in China: A Panel Granger Causality Analysis". *Sustainability*, 8(233), pp. 1-13. DOI: 10.3390/su8030233.

Pfaff, B. (2008) "VAR, SVAR and SVEC Models: Implementation within R Package Vars". *Journal of Statistical Software*, 27(4), pp. 1-32.

Saidi, K., Rahman, M. M., and Saadaoui, A. (2017) "The Causal Relationship among Environmental Quality, Economic Growth and Energy Use: New Evidence from Five OPEC Countries". *In 1st International Conference on Energy, Finance and the Macroeconomy Book of Abstracts (ICEFM-2017)*. Montpellier Business School.

Salahuddin, M., and Gow, J. (2014) "Economic Growth, Energy Consumption and CO_2 Emissions in Gulf Cooperation Council Countries". *Energy*, 73, pp. 44-58.

Salahuddin, M., and Khan, S. (2013) "Empirical Link between Economic Growth, Energy Consumption and CO_2 emission in Australia". *The Journal of Developing Areas*, 47(2), pp. 81-92. DOI: 10.1353/jda.2013.0038.

Sari, R., and Soytas, U. (2009) "Are Global Warming and Economic Growth Compatible? Evidence from Five OPEC Countries?". *Applied Energy*, 86(10), pp. 1887-1893.

Suharsono, A., Aziza, A., and Pramesti, W. (2017) "Comparison of Vector Autoregressive (VAR) and Vector Error Correction Models (VECM) for Index of ASEAN Stock Price", in AIP Conference Proceedings 1913, 1, pp. 020032-1-020032-9. AIP Publishing. Doi: 10.1063/1.5016666. International Conference and Workshop on Mathematical Analysis and its Applications (ICWOMAA 2017).

World Bank (2019). World Development Indicators. Per Capita CO2 Emissions of OPEC Countries. [Online] Available at: https://databank.worldbank.org/data/reports.aspx?source=2&series=BX.KLT.DINV.CD.WD&country=#. Accessed 20 June 2019.

World Bank (2019). World Development Indicators. Per Capita Energy Consumption of OPEC Countries. [Online] Available at: https://databank.worldbank.org/data/reports.aspx?source=2&series=BX.KLT.DINV.CD.WD&country=#Accessed 20 June 2019.

World Bank (2019). World Development Indicators. Per Capita GDP of OPEC Countries. [Online] Available at: https://databank.worldbank.org/data/reports.aspx?source=2&series=NY.GDP.PCAP.CD&country=#. Accessed 20 June 2019.

Appendices

Table 5. Estimation of the VAR Model

Variables	Coefficient	Standard Error	t	P-value
LnPer Capita GDP				
LnPer Capita GDP				
L1	0.819***	0.07	10.95	0.000
L2	-0.072	0.07	-1.00	0.321
LnOil Production				
L1	0.464	0.31	1.48	0.141
L2	-0.136	0.31	-0.43	0.668
LnPer Capita Energy Consumption				
L1	-0.430***	0.16	-2.61	0.010
L2	0.177	0.17	1.04	0.299
LnPer Capita CO_2 Emissions				
L1	1.406***	0.46	3.02	0.003
L2	-0.671	0.47	-1.41	0.161
Constant	0.815	0.83	0.98	0.328
LnOil Production				
LnPer Capita GDP				
L1	-0.038**	0.01	-2.10	0.037
L2	0.025	0.01	1.47	0.143
LnOil Production				
L1	0.963***	0.07	12.66	0.000
L2	-0.043	0.07	-0.57	0.570

Table 5. (Continued)

Variables	Coefficient	Standard Error	t	P-value
LnPer Capita Energy Consumption				
L1	0.074*	0.03	1.86	0.065
L2	-0.073*	0.04	-1.79	0.075
LnPer Capita CO_2 Emissions				
L1	-0.207*	0.11	-1.84	0.068
L2	0.231**	0.11	2.01	0.046
Constant	0.445**	0.20	2.22	0.028
LnPer Capita Energy Consumption				
LnPer Capita GDP				
L1	-0.047	0.09	-0.48	0.632
L2	-0.018	0.09	-0.19	0.851

LnOil Production				
L1	0.420	0.41	1.01	0.314
L2	-0.346	0.42	-0.82	0.411
LnPer Capita Energy Consumption				
L1	0.747***	0.21	3.41	0.001
L2	-0.285	0.22	-1.26	0.208
LnPer Capita CO_2 Emissions				
L1	0.346	0.61	0.56	0.576
L2	0.187	0.63	0.30	0.768
Constant	3.032***	1.10	2.75	0.007
LnPer Capita CO_2 Emissions				
LnPer Capita GDP				
L1	-0.018	0.03	-0.54	0.588
L2	-0.002	0.03	-0.09	0.932
LnOil Production				
L1	0.200	0.14	1.39	0.166
L2	-0.166	0.14	-1.15	0.254
LnPer Capita Energy Consumption				
L1	0.014	0.07	0.19	0.852
L2	-0.178**	0.07	-2.29	0.023
LnPer Capita CO_2 Emissions				
L1	0.800***	0.21	3.75	0.000
L2	0.322	0.21	1.48	0.142
Constant	0.975**	0.38	2.56	0.011

Source: Author's calculation, 2019

*Notes: L1 and L2 mean lag 1 and lag 2, respectively; ***, ** and * denote statistical significance at 1%, 5% and 10%, respectively*