The causal relationship among environmental quality, economic growth and energy use: new evidence from five OPEC countries

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Abstract

This paper aims to explore the relationships between environmental quality, economic growth and energy use. A panel data set of 25 years (1990-2014), for five OPEC countries (Algeria, Nigeria, Indonesia, Saudi Arabia and Venezuela) is used, and panel unit root tests, panel co-integration tests and panel Granger causality tests are employed as estimation strategies. Our results show that in the long-run there are two-way causal relationships between GDP and energy consumption for all countries. Bilateral causal relationships between GDP and CO_2 emissions are also observed in all countries except Algeria where no causality is found. The same relationships are also observed between energy consumption and CO_2 emissions in all countries with an exception for Venezuela where unidirectional causality running from CO_2 to energy consumption is found.

Keywords: Economic growth, Energy use, CO_2 emissions, VECM

1. Introduction

The causality nexus between economic growth and environmental pollution has been a source of great controversy for a very long time. CO_2 emissions have increased dramatically over the last century due to human activities, principally by the use of fossil fuels as well as changes in land use that are directly linked with economic growth and development. The causal connection between economic growth and different indicators of environmental degradation has been extensively explored in the recent years by the Environmental Kuznets Curve (EKC) models globally, regionally or country wise by several authors. This is because the global warming and other environmental problems have become a great concern for sustainable development for each country of the world. Therefore, the importance of such study will never end for any country where policy makers want to maintain environmental quality over time.

Economic growth is one of the most important factors affecting projected changes in the world's energy use. Since the 1970s there have been a number of empirical studies attempting to examine the causal link between economic growth and energy use. Even with fairly extensive empirical research undertaken within this topic, the results regarding causality direction have been largely inconclusive. Saidi and Hammami (2015) quite clearly state that the empirical evidence from previous studies on this subject shows that the causal relationship between energy consumption and economic growth differs from country to country and from region to region over time. The reasons can be attributed to differences among countries, statistical techniques employed, time horizons and data sets. This, in the end, makes the role of energy rather a controversial topic in economic literature. However, knowing the direction of causality has significant implications on economic policy. For instance, should the state employ structural policies aimed at the reduction of energy consumption or should it employ additional resources in subsidizing energy prices? Securing long-term and stable energy supply depends on the analysis of energy consumption-economic growth nexus.

Against this backdrop this paper attempts to investigate the causal relationship between energy use, CO_2 emissions and economic growth of five OPEC countries: Algeria, Nigeria, Saudi Arabia, Venezuela and Indonesia. The selection for these five countries is based on the following rationale: Algeria, Indonesia and Nigeria have limited oil reserves with the pressing development needs; on the other hand, Saudi Arabia and Venezuela have the largest oil reserves. In Africa, Algeria is the first country who successfully nationalized its hydrocarbons industry in 1971, and it remains an important and strategic member of OPEC. Nigeria is a rather stirring member of the organization. Its oil production rose sharply based on the deep offshore developments, and the country exceeds its quota quite often. In South East Asia, Indonesia is a country which is now a net importer of energy. In the Middle East, Saudi Arabia is the second largest in the world oil reserves just after Venezuela; its status is the largest producer and exporter, and it focuses almost any spare capacity. In South America, under President Hugo Chávez, Venezuela has taken a much more active role in OPEC. Venezuela has big oil sands reserves and the country has the largest oil reserves in the world, ahead of Saudi Arabia.

The rest of the paper is organized as follows: Section 2 gives a brief review of past empirical studies, Section 3 presents empirical model and data source, Section 4 provides estimation methodology, Section 5 reports the empirical results and their analysis and finally, Section 6 concludes the study with policy implications.

2. Literature review

Nowadays, three kinds of research categories exist in the literature looking at economic growth, environmental pollution and energy use relations. The first category of the literature focuses on the causal links between environmental pollution and economic development. Past studies on this issue provide conflicting results (Wagner, 2008; Muller-Furstenberger and Wagner, 2007). Some of the indicators that have been employed as proxies for environmental pollution are CO_2 (carbon dioxide) and SO_2 emissions (World Bank, 2007). In general, the relationship between environmental pollution and economic development can be modeled by the so-called EKC (environmental Kuznets curve), indicating that pollution increases together with increases in the income level up to a certain turning point, after which increases in the income level result in a decline in the level of pollution. In other words, there is an inverted-U-shaped relationship between environmental pollution and economic development. The empirical results of Panayotou (1993), Selden and Song (1994), Martinez-Zarzoso and Bengochea-Morancho (2004) are consistent with the EKC hypothesis. However, Dinda (2004) has critiqued much of the EKC hypothesis, arguing that the causation could run from emissions to income whereby emissions occur in the production process and income increases. In addition, there are several studies that have examined the causal relationship between economic growth and CO_2 emissions [see, for example, Soytas et al. (2007) in US; Halicioglu (2009) in Turkey; Jalil and Mahmud (2009) in China; Soytas and Sari (2009) in Turkey; Sari and Soytas (2009) in OPEC countries; and Ghosh (2010) in India].

The second category of the literature investigates the link between energy use and economic development. This has been the most widely investigated in the last three decades. However, existing outcomes have varied considerably. Some studies have chosen to explore single countries, while others have investigated many countries simultaneously in a panel data analysis framework. Some studies, like Fatai et al. (2004) compared the relationship between energy consumption and economic growth of New Zealand economy with Australia and different Asian economies. There are four hypotheses to examine this relation. First, the *growth hypothesis* refers to a case where energy consumption plays a crucial role in stimulating economic growth. In this case, there is uni-directional causality from energy consumption to economic growth. With respect to this hypothesis, an energy conservation policy to reduce energy consumption is not desirable as they will retard the process of economic growth and development of a country. Second, the *conservation hypothesis* refers to a case where there is unidirectional causality running from economic growth to energy consumption. Some studies found the relationship to be true, and some found otherwise. *Feedback hypothesis* is the third plausible hypothesis found by some studies. The feedback hypothesis refers to a case where there is an interdependent relationship between energy consumption and economic growth. In the sense of Granger causality, energy consumption and economic growth are bi-directional causality. Finally, *neutrality hypothesis* refers to a case where energy consumption and economic growth are unrelated. Therefore, change in energy consumption does not affect economic growth or vice versa. In this context, energy conservation policies devoted to reduce energy use will not affect per capita GDP at all. Table 1 provides the summary of review results of past studies that examine the relationship between energy use, carbon dioxide emissions and economic growth.

Table 1:
The summary of studies on energy consumption, CO_2 emissions and economic growth

Author (s)	Country	Period	Variables	Methodology	Causality results
			Energy use and economic growth		
1.Conservation hypothesis (Unidirectional causality from GDP to EC)					
Zhang and Cheng (2009)	China	1960-2007	GDP, EC	Granger causality	GDP→EC
Jamil and Amed (2010)	Pakistan	1960-2008	GDP, EC	J-J; Granger causality - VECM	GDP→EC
Salahuddin and Gow (2014)	GCC: countries	1980-2012	GDP, EC	Cointegration, Granger causality	GDP→EC
Kais et al. (2015)	67 Countries	1990-2012	ITC, EC, GDP, FD	Technique of GMM	GDP→EC
2.Growth hypothesis (Unidirectional causality from EC to GDP)					
Alkhathlan and Javid (2013)	Saudi Arabia	1980-2011	EC, CO_2, Y	ARDL	EC→GDP
Saboori et al. (2014)	OECD	1960-2008	EC, CO_2, GDP	VAR-Granger causality	EC→GDP
Yang and Zhao (2014)	India	1970-2008	EC, CO_2, GDP	Granger causality	EC→GDP
Tang and Abosedra, (2014)	MENA	2001-2009	EC, GDP	GMM estimator	EC→GDP
3.Feedback hypothesis (bidirectional causality between GDP and EC)					
Sbia et al. (2014)	UAE	1957-2011	FDI, CO_2, EC, GDP	ARDL	GDP↔EC
Nasreen and Anwar (2014)	Asian countries	1980-2011	TR, EC, GDP	VECM-Granger causality	GDP↔EC
Shahbaz et al. (2013)	Malaysia	1971-2008	FDI, EC, Y	VECM-Granger causality	GDP↔EC
Kais and Sami (2014)	Tunisia	1974-2011	EC, GDP	Johansen cointegration technique.	EC↔ GDP
Fuinhas and Marques (2011)	Portugal, Italy, Greece, Spain and Turkey	1965-2009	EC, GDP	ARDL bounds test approach	EC↔ GDP
4.Neutrality hypothesis (no causal relationship between EC and GDP)					
Yildrim et al. (2012)	11 countries	1975-2012	EC, GDP	Bootstrapped autoregressive	EC≠GDP
Payne (2009)	USA	1949-2006	EC, Y	Toda-Yamamoto causality	EC ≠ GDP
Soyatas et al. (2007)	U.S	1960-2004	EC, CO2, GDP,	Granger causality	EC ≠ GDP
			CO_2 emissions and economic growth		
Soytas et al. (2007)	USA	1960-2004	GDP, EC, CO_2	Granger causality test. Generalized variance decomposition	GDP→CO_2
Halicioglu (2009)	Turkey	1960-2005.	CO_2, GDP, EC, TR	Cointegration	GDP ↔CO_2
Jalil and Mahmed (2009)	China	1975–2005	CO2, GDP	EKC	GDP→CO_2
Soytas and Sari (2009)	Turkey	1960–2000	EC, CO_2, L, K, Y	Co-integration ; Granger causality test	In short-run: GDP ↔CO_2
Sari and Soytas (2009)	Five OPEC countries	1971–2002	GDP, EC, CO_2	Co-integration test; VAR	CO_2 →GDP
Ghosh (2010)	India	1971-2006	GDP, CO_2	Contegration test; ARDL	CO_2 ≠ GDP
			Energy use, CO_2 emissions and economic growth		

Zhang and Cheng (2009)	China	1960-2007	EC, CO_2, Y	VAR model based on Toda and Yamamoto [1995] procedures	GDP → EC✸EC→CO_2 EC ≠ GDP✸CO_2 ≠ GDP
Farhani and Rejeb (2012)	15 MENA countries	1973-2008	Y, EC, CO_2	FMOLS and DOLS.	EC ≠ GDP✸EC≠ CO_2 EC→GDP✸EC→CO_2
Lean and Smyth (2010)	Five ASEAN countries	1980-2006	Y, EC, CO_2	EKC	GDP → EC✸GDP→CO_2✸EC→CO_2
Pao and Tsai (2010)	Brazil	1980-2007	CO_2, EC, GDP	Cointegration Grey, Granger causality, prediction model (GM)	GDP lnp CO2✸EC lnp CO2 GDP↔CO2✸GDP↔EC
Pao et al. (2011)	Russia	1990-2007	GDP, EC, CO_2	Granger causality VEC, JJ cointegration	GDP↔CO2✸GDP↔EC✸EC↔CO2
Kais and Sami (2015)	58 countries	1990-2012	GDP, CO_2, EC	GMM estimation, Simultaneous equation models	GDP↔EC✸EC↔GDP✸CO_2↔GDP

Notes: *EC = energy consumption; GDP = real or nominal GDP or GNP; J-J = Johansen-Juselius; ARDL = Autoregressive distributed lags; VAR = Vector autoregressive model; VECM = Vector error correction model.* ***GDP → EC*** *= causality runs from economic growth to energy consumption..* ***EC → GDP*** *= causality runs from energy consumption to economic growth..* ***EC ↔ GDP****= There is a bidirectional causality.* ***EC ≠GDP*** *= No causal relationship is found between energy consumption and economic growth.* ***Lnp =*** *long run positive relationship.*

The last category of the literature employs a multivariate framework to examine the causal links between the variables by incorporating all the variables of interest in a single equation. This literature focuses on the links between CO_2 emissions, energy consumption, and economic development. Here also the obtained results are mixed based on the different adopted approaches and data period. The summary of results is also noted in Table 1.

The above discussion reveals that, to the best of our knowledge, there is a lacking of an empirical study in the OPEC group especially based on the countries of our study. Therefore, this study is an attempt to fill up this gap. Our research will contribute to the existing literature with new findings, and the policy makers of these countries are expected to be benefited in terms of adoption and execution of right policies.

3. Empirical model and data

3.1. Modeling

Following the earlier literature (Halicioglu 2009; Pao and Tsai 2010; Yildirim 2014; Lin and Lin 2015) in energy economics, we can frame our empirical model as follows:

$$NC = f(GDP,\ ENERGY, DEP, FDI, URBAN) \quad \textbf{(1)}$$

Where NC is the total CO_2 emissions, GDP = gross domestic product (proxied for economic growth), DEP = population density, FDI = foreign direct investment and URBAN = urbanization. Literature shows that (GDP) (Kais and Sami, 2016; Saidi and Mbarek, 2016), energy consumption (Soytas and Sari 2009; Saidi and Hammami, 2015), foreign direct investment (FDI) (Kim and Adilov 2012; Blanco et al. 2013), population density (Mahmood and Chaudhary, 2012; Ohlan, 2015), and urbanization (Sadorsky, 2014; Ponce de Leon Barido and Marshall, 2014) affect CO_2 emissions. Therefore, we have included these variables as explanatory variables in our above model.

3.2. Data

The paper focuses on five OPEC countries: Algeria, Indonesia, Nigeria, Saudi Arabia, and Venezuela. The reasons for selecting these countries are noted in sections 1. Moreover, the availability of the required data is also another influencing factor for choosing these countries. The data cover the period 1990-2014. Carbon dioxide emissions are measured in metric tons per capita, GDP per capita is measured in US Dollar, energy consumption is measured in kiloton of oil equivalent, population density is measured by people per sq. km of land area, urbanization is measured by the of urban population, and the FDI is the inflow to GDP. Data have been drawn from the database of the World Bank (World Development Indicators, WDI, 2016). All variables are transformed into the natural logarithm form, and data are annual.

Table 2:
Descriptive Statistics of data

Country	Variable	Mean	Std. Dev.	Minimum	Maximum
Algeria	NC	3.122626	0.244878	2.668328	3.531428
	GDP	4.046263	0.058961	3.962505	4.131644
	ENERGY	2.981801	0.064357	2.902126	3.097868
Indonesia	NC	1.466656	0.391309	0.824342	2.303781
	GDP	3.822060	0.095820	3.651017	4.001452
	ENERGY	2.862118	0.061690	2.735212	2.937912
Nigeria	NC	0.545551	0.134189	0.322040	0.759211
	GDP	3.557583	0.119071	3.437685	3.751237
	ENERGY	2.849510	0.036011	2.730493	2.900318
Saudi Arabia	NC	15.34484	2.545293	10.22946	18.97763
	GDP	4.590981	0.053899	4.526061	4.694930
	ENERGY	3.701649	0.074479	3.549646	3.831821
Venezuela	NC	15.34484	2.545293	10.22946	18.97763
	GDP	4.590981	0.053899	4.526061	4.694930
	ENERGY	3.701649	0.074479	3.549646	3.831821

Note: *CO_2 emissions (NC) are measured in metric tons of CO_2 emitted per capita. Economic growth (GDP) is measured in 2005 per capita. Energy consumption (ENERGY) is measured in kg of oil equivalent per capita.*

4. Methodology

The main objective of our empirical analysis is to determine the dynamic causal links between the quality of the environment, energy use and GDP in a set of five OPEC countries. The procedure to test the relationships between these variables consists of three stages, namely panel unit root tests, panel cointegration tests and panel Granger causality tests. We will perform the three types of tests, step by step blow. To estimate the relationship between the variables, we outline the following model (2), (3) and (4):

$$lnNC_{it} = \gamma_0 + \gamma_1 lnGDP_{it} + \gamma_2 lnENERGY_{it} + \gamma_3 lnDEP_{it} + \gamma_4 lnFDI_{it} + \gamma_5 URBAN_{it} + \varepsilon_{it} \quad \textbf{(2)}$$

$$lnGDP_{it} = \beta_0 + \beta_1 lnNC_{it} + \beta_2 lnENERGY_{it} + \beta_3 lnDEP_{it} + \beta_4 lnFDI_{it} + \beta_5 URBAN_{it} + \varepsilon_{it} \quad \textbf{(3)}$$

$$lnENERGY_{it} = \alpha_0 + \alpha_1 lnGDP_{it} + \alpha_2 lnNC_{it} + \alpha_3 lnDEP_{it} + \alpha_4 lnFDI_{it} + \alpha_5 URBAN_{it} + \varepsilon_{it} \quad \textbf{(4)}$$

Where, lnGDP is the logarithm of GDP per capita, lnENERGY is the logarithm of the energy consumption per capita and lnNC is the logarithm of the CO_2 emissions per capita.

lnFDI is the logarithm of foreign direct investment and lnDEP is the logarithm of the population density. Finally, URBAN is the share of urban population. γ_0, β_0 and α_0 are constants. We adopt a four step process to determine causal relationships.

4.1. The analysis of the stationary series

The first step in our analysis is to ensure the stationarity of the series or of the integration order of each. This is important since the use of non-stationary variables in a regression may have consequences such as invalid significance tests (Granger, 1969). A time series is stationary if it's mean and variance do not vary with time, otherwise it is called non-stationary. Nelson and Plosser (1982) believe that most economic variables are not stationary. The analysis of non-stationary time series has become a major exercise in the current econometric practice to avoid the problems posed by the use of non-stationary variables. In this paper, we implement Augmented Dickey and Fuller (1979), Phillips & Perron (1988) test for verifying the stationarity of series.

4.2. Analysis of the co-integration

After determining the order of integration of the series, the next step is to detect the existence of co-integration relationships. If the variables are integrated in the same order, it is possible that there is an overall movement of the latter. The co-integration tests, which are considered an extension of the stationarity tests, can detect the built-in variables of the same order that have the same stochastic trend and hence a co-integration relationship. The concept of co-integration can be defined as a systematic long-term co-movement between two or more economic variables, (Yoo, 2006). To test the co-integration and determine the number of co-integration relationships, we have used Johansen-Juselius test following the earlier studies.

4.3. Causality test and speed adjustment

When the results of co-integration test support the no cointegration relationship between variables, we estimate a VAR model that can recover the impulse response functions and variance decomposition mistakes. However, if the cointegration tests confirming the presence of long-term relationships, the residues of long-term equilibrium equations (2), (3) and (4) are used to estimate the error correction models (*ECM*) in the third step. The ECM is a restriction of VAR. It contains a term cointegration represented by an error correction term (*ECT*) and forced the endogenous variables to converge to the cointegration relationships while enabling dynamic adjustments of the short term. The error correction implies that changes in endogenous variables are a function of the level of imbalance in the cointegration relationship it recovers. ECT is the imbalance correction method and determination of short-term and long term relationships between variables. The error correction model is as follows:

$$\begin{aligned}\Delta lnNC = \gamma_{i0} &+ \sum_{k=1}^{P} \gamma_{i1k}\, \Delta lnNC_{it-k} + \sum_{k=1}^{P} \gamma_{i2}\, \Delta lnGDP_{it-k} + \sum_{k=1}^{P} \gamma_{i3}\, \Delta lnENERGY_{it-k} \\ &+ \sum_{k=1}^{P} \gamma_{i4}\, \Delta lnDEP_{it-k} + \sum_{k=1}^{P} \gamma_{i5}\, \Delta lnFDI_{it-k} + \sum_{k=1}^{P} \gamma_{i6}\, \Delta URBAN_{it-k} \\ &+ \gamma_{i7} ECT_{NC,t-1} + \varepsilon_{it}\end{aligned} \quad (5)$$

$$\begin{aligned}\Delta lnGDP = \beta_{i0} &+ \sum_{k=1}^{P} \beta_{i1k}\, \Delta lnGDP_{it-k} + \sum_{k=1}^{P} \beta_{i2}\, \Delta lnNC_{it-k} + \sum_{k=1}^{P} \beta_{i3}\, \Delta lnENERGY_{it-k} \\ &+ \sum_{k=1}^{P} \beta_{i4}\, \Delta lnDEP_{it-k} + \sum_{k=1}^{P} \beta_{i5}\, \Delta lnFDI_{it-k} + \sum_{k=1}^{P} \beta_{i6}\, \Delta URBAN_{it-k} \\ &+ \beta_{i7} ECT_{GDP,\ t-1} + \varepsilon_{it}\end{aligned} \quad (6)$$

$$\begin{aligned}\Delta lnENERGY = \alpha_{i0} &+ \sum_{k=1}^{P} \alpha_{i1k}\, \Delta lnENERGY_{it-k} + \sum_{k=1}^{P} \beta_{i2}\, \Delta lnGDP_{it-k} + \sum_{k=1}^{P} \alpha_{i3}\, \Delta lnCN_{it-k} \\ &+ \sum_{k=1}^{P} \alpha_{i4}\, \Delta lnDEP_{it-k} + \sum_{k=1}^{P} \alpha_{i5}\, \Delta lnFDI_{it-k} + \sum_{k=1}^{P} \alpha_{i6}\, \Delta URBAN_{it-k} \\ &+ \beta_{i7} ECT_{ENERGY,\ t-1} + \varepsilon_{it}\end{aligned} \quad (7)$$

Where Δ is the first difference operator, k (k = 1, ..., p) is the optimal number of delay determined by the AIC information criteria. ε_{it} is the error term. The term ECT_{t-1} in each of the equations is the offset term of error correction of a period, derived long term cointegration relationships, Equations (2) to (4) will be as follows:

$$\begin{aligned}ECT_{NC,it} = lnNC_{it} - \widehat{\gamma_{i1}} lnGDP_{it} - \widehat{\gamma_{i2}} lnENERGY_{it} - \widehat{\gamma_{i3}} lnDEP_{it} - \widehat{\gamma_{i4}} lnFDI_{it} \\ - \widehat{\gamma_{i5}} URBAN_{it}\end{aligned}$$

$$ECT_{GDP,it} = lnGDP_{it} - \widehat{\beta_{\iota 1}} lnNC_{it} - \widehat{\beta_{\iota 2}} lnENERGY_{it} - \widehat{\beta_{\iota 3}} lnDEP_{it} - \widehat{\beta_{\iota 4}} lnFDI_{it} - \widehat{\beta_{\iota 5}} URBAN_{it}$$

$$ECT_{ENERGY,it} = lnENERGY_{it} - \widehat{\alpha_{\iota 1}} lnGDP_{it} - \widehat{\alpha_{\iota 2}} lnNC_{it} - \widehat{\alpha_{\iota 3}} lnDEP_{it} - \widehat{\alpha_{\iota 4}} lnFDI_{it} - \widehat{\alpha_{\iota 5}} URBAN_{it}$$

The subscript i denotes the country. The γ_{i7}, β_{i7} and α_{i7} are the adjustment coefficients that tell us about the existence of long-term relationship.

4.4. The determination of long-term causal relationships

It is recognized that the ordinary least squares method does not always give consistent estimators. For this, Kao and Chiang (1999) proposed the DOLS (*Dynamic Ordinary Least Square*) estimator. This estimator does not give great importance to the heterogeneity of individuals. To solve this problem, Pedroni (2001, 2004) proposed the FMOLS (*Fully Modified Ordinary Least Square*) estimator which allows taking into account the heterogeneity of individuals as well as the problem of endogeneity and autocorrelation. These estimators (DOLS and FMOLS) do not provide estimates that are effective for small sample size; they can control the endogeneity problem of regressors and the problem of autocorrelation (Ramirez, 2006). The model estimated here is specified as follows:

$$lnNC_{it} = \gamma_{i0} + \gamma_{i1} lnGDP_{it} + \gamma_{i2} lnENERGY_{it} + \sum_{k=-k_i}^{k_i} \theta_{i1k} \Delta lnGDP_{it-k} + \sum_{k=-k_i}^{k_i} \theta_{i2k} \Delta lnENERGY_{it-k} + \varepsilon_{it} \quad \textbf{(8)}$$

$$lnGDP_{it} = \beta_{i0} + \beta_{i1} lnNC_{it} + \beta_{i2} lnENERGY_{it} + \sum_{k=-k_i}^{k_i} \theta_{i1k} \Delta lnNC_{it-k} + \sum_{k=-k_i}^{k_i} \theta_{i2k} \Delta lnENERGY_{it-k} + \varepsilon_{it} \quad \textbf{(9)}$$

$$lnGDP_{it} = \beta_{i0} + \beta_{i1} lnNC_{it} + \beta_{i2} lnENERGY_{it} + \sum_{k=-k_i}^{k_i} \theta_{i1k} \Delta lnNC_{it-k} + \sum_{k=-k_i}^{k_i} \theta_{i2k} \Delta lnENERGY_{it-k} + \varepsilon_{it} \quad \textbf{(10)}$$

5. Results and Discussion

5.1. Unit root test

Before estimating relationships between variables, there is a need to determine the order of integration of each variable to avoid making misleading estimates. For this, we apply the unit root tests to the level and first difference on the logarithm of the variables GDP per capita, energy consumption, CO_2 emissions, population density, urban population and foreign direct investment. We perform here the unit root tests of ADF and Phillips & PP Perron. The ADF and PP tests test the null hypothesis of the presence of a unit root (non stationarity) against the alternative hypothesis of no unit root (stationarity). The test results are given in Table 3 below for the five OPEC countries considered here.

Table 3

Results of panel unit root tests

Countries	Variables	ADF		PP	
		ADF Test at Level		*PP Test at Level*	
		T-Statistics	Prob-Value	T-Statistics	Prob-Value
Algeria	**lnNC**	0.543713	0.8260	0.557337	0.8295
	lnGDP	2.322897	0.9933	1.551734	0.9663
	lnENERGY	2.217841	0.9915	2.217841	0.9915
	lnDEP	2.677080	0.9967	12.35653	1.0000
	lnFDI	-0.993551	0.2781	-0.992216	0.2787
	URBAN	-3.151344	0.0030	16.28492	1.0000
		ADF Test at 1st Difference		*PP Test at 1st Difference*	
	lnNC	-7.833417	**0.0000***	-8.090521	**0.0000***
	lnGDP	-1.419016	**0.0141****	-2.491183	**0.0153****
	lnENERGY	-4.071953	**0.0003***	-4.066208	**0.0003***
	lnDEP	-1.214027	**0.0197****	21.93147	**0.0000***
	lnFDI	-5.235872	**0.0000***	-6.600849	**0.0000***
	URBAN	-6.397212	**0.0000***	-5.055978	**0.0000***
		T-Statistics	*Prob-Value*	*T-Statistics*	*Prob-Value*
Indonesia	**lnNC**	2.099931	0.9888	3.565301	0.9997
	lnGDP	3.821522	0.9998	3.385324	0.9995
	lnENERGY	2.812105	0.9978	3.309191	0.9994
	lnDEP	-0.104398	0.6354	23.64797	0.9999
	lnFDI	-1.003145	0.2744	-1.003145	0.2744
	URBAN	0.179647	0.7291	6.872141	1.0000
		T-Statistics	*Prob-Value*	*T-Statistics*	*Prob-Value*
	lnNC	-6.591465	**0.0000***	-6.591465	**0.0000***
	lnGDP	-2.680784	**0.0097***	-2.606209	**0.0116****
	lnENERGY	-4.348613	**0.0001***	-4.363378	**0.0001***
	lnDEP	-1.311274	**0.0169****	-6.088833	**0.0000***
	lnFDI	-4.204203	**0.0002***	-4.188098	**0.0002***
	URBAN	-1.990933	**0.0465****	-2.023554	**0.0434****
		T-Statistics	*Prob-Value*	*T-Statistics*	*Prob-Value*
Nigeria	**lnNC**	-0.287881	0.5715	-0.287881	0.5715
	lnGDP	2.226648	0.9917	1.904070	0.9833
	lnENERGY	-0.752375	0.3798	-0.752375	0.3798
	lnDEP	-0.653427	0.5342	190.9873	0.9999
	lnFDI	-1.166001	0.2149	-1.148491	0.2211
	URBAN	1.509462	0.9633	21.17624	0.9999
		T-Statistics	*Prob-Value*	*T-Statistics*	*Prob-Value*
	lnNC	-4.455336	**0.0001***	-4.455336	**0.0001***

	lnGDP	-3.209503	0.0026*	-3.162791	0.0030*
	lnENERGY	-1.216084	0.0197**	-3.921663	0.0004*
	lnDEP	-0.886590	0.0319**	0.985627	0.0008*
	lnFDI	-5.410890	0.0000*	-6.676606	0.0000*
	URBAN	-0.028142	0.0663**	-2.148142	0.0063*
		T-Statistics	*Prob-Value*	*T-Statistics*	*Prob-Value*
Saudi Arabia	lnNC	0.374197	0.7844	0.399825	0.7911
	lnGDP	2.253933	0.9921	1.944403	0.9847
	lnENERGY	1.624395	0.9695	2.516058	0.9957
	lnDEP	-0.741552	0.3824	18.89548	0.9999
	lnFDI	-1.702917	0.0834	-1.289122	0.1765
	URBAN	3.345903	0.9994	7.464238	1.0000
		T-Statistics	*Prob-Value*	*T-Statistics*	*Prob-Value*
	lnNC	-5.176271	0.0000*	-5.176271	0.0000*
	lnGDP	-3.167570	0.0029*	-3.186130	0.0028*
	lnENERGY	-1.137828	0.2228	-5.438697	0.0000*
	lnDEP	-0.824836	0.3460	-1.384506	0.1499
	lnFDI	-3.531513	0.0011*	-3.440635	0.0015*
	URBAN	-3.161000	0.0030*	-3.040006	0.0040*
		T-Statistics	*Prob-Value*	*T-Statistics*	*Prob-Value*
Venezuela	lnNC	0.374197	0.7844	0.399825	0.7911
	lnGDP	2.253933	0.9921	1.944403	0.9847
	lnENERGY	1.624395	0.9695	2.516058	0.9957
	lnDEP	-1.654326	0.8754	13.65483	1.0000
	lnFDI	-1.702917	0.0834	-1.289122	0.1765
	URBAN	0.197058	0.7339	3.074349	0.9989
		T-Statistics	*Prob-Value*	*T-Statistics*	*Prob-Value*
	lnNC	-5.176271	0.0000*	-5.176271	0.0000*
	lnGDP	-3.167570	0.0029*	-3.186130	0.0028*
	lnENERGY	-1.137828	0.2228	-5.438697	0.0000*
	lnDEP	-2.006271	0.0455**	-19.10910	0.0001*
	lnFDI	-3.531513	0.0011*	-3.440635	0.0015*
	URBAN	-2.255904	0.0261**	-2.040030	0.0419**

Notes: *ADF= Augmented Dickey & Fuller; PP= Phillips and Perron; (*) and (**) indicate the significance levels at 1% and 5%, respectively.*

Generally, the results in Table 3 indicate that the logarithm series of CO_2 emissions per capita, energy consumption, GDP, population density, and foreign direct investment and urbanization are integrated of the same order 1. Indeed one hand, the ADF and PP tests, generally do not reject the null hypothesis of the presence of a unit root. The variables of CO_2 emissions per capita, GDP per capita, energy consumption per capita, population density, FDI and urbanization are not stationary in level. However, the null hypothesis of the presence of a unit root is rejected in all OPEC countries for all variables in first difference.

5.2. Cointegration test

After showing that variables in our analysis are integrated in the same order 1, it is necessary to realize the co-integration test. As stated above, we implement the co-integration tests of Johansen (1988). The number of co-integration relationships is determined through two statistics, trace Statistic and Max-Eigen Statistic. The null hypothesis of the test track is that there is at most co-integrating relations, against the alternative hypothesis that there is more than at most. The null hypothesis of the maximum of the test is that there are exactly at most co-integration relationships against the alternative hypothesis that there is exactly most 1. These tests are conducted sequentially. The Johansen cointegration test is sensitive to the number of delays used. The co-integration tests results are given in Table 4.

Table 4:

Results of the cointegration test of Johansen (1988)

	Hypothesized	Eigenvalue	Trace Statistic	5% Critical Value	Prob.**	Hypothesized	Eigenvalue	Max-Eigen Statistic	5% Critical Value	Prob.**
Algeria	**None ***	0.975686	182.6145	95.75366	0.0000	**None ***	0.975686	85.48371	40.07757	0.0000
	At most 1*	0.837229	97.13078	69.81889	0.0001	**At most 1***	0.837229	41.75448	33.87687	0.0047
	At most 2*	0.640047	55.37630	47.85613	0.0084	**At most 2***	0.640047	23.50096	27.58434	0.1531
	At most 3*	0.575430	31.87533	29.79707	0.0284	**At most 3***	0.575430	19.70362	21.13162	0.0782
	At most 4	0.387341	12.17171	15.49471	0.1489	**At most 4**	0.387341	11.26877	14.26460	0.1413
	At most 5	0.038498	0.902945	3.841466	0.3420	**At most 5**	0.038498	0.902945	3.841466	0.3420
	Hypothesized	**Eigenvalue**	**Trace Statistic**	**5% Critical Value**	**Prob.****	**Hypothesized**	**Eigenvalue**	**Max-Eigen Statistic**	**5% Critical Value**	**Prob.****
Indonesia	**None ***	0.904823	147.6992	95.75366	0.0000	**None ***	0.904823	54.09643	40.07757	0.0007
	At most 1*	0.812879	0.812879	69.81889	0.0002	**At most 1***	0.812879	0.812879	33.87687	0.0129
	At most 2*	0.654965	0.654965	47.85613	0.0091	**At most 2***	0.654965	0.654965	27.58434	0.1190
	At most 3*	0.529240	0.529240	29.79707	0.0406	**At most 3***	0.529240	0.529240	21.13162	0.1571
	At most 4	0.297847	0.297847	15.49471	0.1059	**At most 4**	0.297847	0.297847	14.26460	0.3654
	At most 5*	0.199539	0.199539	3.841466	0.0237	**At most 5***	0.199539	0.199539	3.841466	0.0237
	Hypothesized	**Eigenvalue**	**Trace Statistic**	**5% Critical Value**	**Prob.****	**Hypothesized**	**Eigenvalue**	**Max-Eigen Statistic**	**5% Critical Value**	**Prob.****
Nigeria	**None ***	0.941029	187.7375	95.75366	0.0000	**None ***	0.941029	65.10632	40.07757	0.0000
	At most 1*	0.862699	122.6312	69.81889	0.0000	**At most 1***	0.862699	45.66841	33.87687	0.0013
	At most 2*	0.752584	76.96279	47.85613	0.0000	**At most 2***	0.752584	32.12375	27.58434	0.0121
	At most 3*	0.652258	44.83904	29.79707	0.0005	**At most 3***	0.652258	24.29480	21.13162	0.0173
	At most 4	0.373880	20.54425	15.49471	0.0079	**At most 4**	0.373880	10.76889	14.26460	0.1662
	At most 5*	0.346240	9.775355	3.841466	0.0018	**At most 5***	0.346240	9.775355	3.841466	0.0018
	Hypothesized	**Eigenvalue**	**Trace Statistic**	**5% Critical Value**	**Prob.****	**Hypothesized**	**Eigenvalue**	**Max-Eigen Statistic ($\rho_{\max}$)**	**5% Critical Value**	**Prob.****
Saudi Arabia	**None ***	0.999401	328.0400	95.75366	0.0000	**None ***	0.999401	170.6469	40.07757	0.0001
	At most 1*	0.935895	157.3931	69.81889	0.0000	**At most 1***	0.935895	63.18622	33.87687	0.0000
	At most 2*	0.899212	94.20688	47.85613	0.0000	**At most 2***	0.899212	52.77882	27.58434	0.0000
	At most 3*	0.702183	41.42806	29.79707	0.0015	**At most 3***	0.702183	27.85936	21.13162	0.0049
	At most 4	0.376949	13.56870	15.49471	0.0956	**At most 4**	0.376949	10.88191	14.26460	0.1602
	At most 5	0.110252	2.686789	3.841466	0.1012	**At most 5**	0.110252	2.686789	3.841466	0.1012
	Hypothesized	**Eigenvalue**	**Trace Statistic**	**5% Critical Value**	**Prob.****	**Hypothesized**	**Eigenvalue**	**Max-Eigen Statistic**	**5% Critical Value**	**Prob.****
Venezuela	**None ***	0.992555	260.8393	95.75366	0.0000	**None ***	0.992555	112.7046	40.07757	0.0000
	At most 1*	0.926354	148.1347	69.81889	0.0000	**At most 1***	0.926354	59.99522	33.87687	0.0000
	At most 2*	0.852999	88.13947	47.85613	0.0000	**At most 2***	0.852999	44.09824	27.58434	0.0002
	At most 3*	0.671904	44.04123	29.79707	0.0006	**At most 3***	0.671904	25.63230	21.13162	0.0108
	At most 4*	0.520353	18.40893	15.49471	0.0177	**At most 4***	0.520353	16.89821	14.26460	0.0187
	At most 5	0.063573	1.510720	3.841466	0.2190	**At most 5**	0.063573	1.510720	3.841466	0.2190

Notes: ** denotes rejection of the hypothesis at the 0.05 level*

When the trace statistics are more than the critical value at 5% significance level under none, at most 1, at most 2, at most 3, at most 4 and at most 5 cointegrations, it rejects null hypothesis and indicates stationary presence. The null hypothesis is rejected when trace or Max-Eigen Statistic is greater than the critical value at the 5% threshold. We note that the null hypothesis that none, indicating no cointegration relationship between the variables of CO_2 emissions per capita, energy consumption per capita, population density, FDI, and urbanization in each of the OPEC countries is rejected at the 5% level. For the four countries (Algeria, Indonesia, Nigeria and Saudi Arabia), we cannot reject the null hypothesis that at most 4, the statistics of trace Statistic and Max-Eigen Statistic are lower than the critical values at the 5% threshold. For the five OPEC countries, the null hypothesis are rejected that the ranks of cointegration at most 1, at most 2 and at most 3. The cointegrating rank is equal to 1, 2 and 3.

5.3. The analysis of the long term speed of adjustment

Following the results of cointegration tests, which indicated the presence of long-term relationships in each country of the OPEC, we adopt the error correction method for each country to analyze the long-term fit between the variables. It determines the direction and intensity of short term relationships as well as the long-term speed of adjustment. The procedure is done in two stages. The first is to estimate the models (1) to (3) and recover the corresponding residues to deviations from equilibrium. The second step corresponds to the estimate of the equations (4) to (6) which contain the residues recovered. This step estimates the coefficients which correspond to adjustment speeds in short and long-term. Table 5 shows the estimated results.

Table 5
Results of the estimation of the long term speed of adjustment

Country	**Sources of influence (independent variables)**						
Algeria	**Short-term**						**Speed adj. of long term**
Dependent variable	**ΔlnCN**	**ΔlnGDP**	**ΔlnENERGY**	**ΔlnDEP**	**ΔlnFDI**	**ΔURBAN**	**ECT**
ΔlnCN	-	6.37 (0.18)	1.43 (0.62)	51.63 (0.066)***	0.12 (0.17)	-74.18 (0.067) ***	**-0.69 (0.00)***
ΔlnGDP	0.013 (0.09)***	-	0.31 (0.03)**	-3.20 (0.00)*	-0.003 (0.42)	4.71 (0.00)*	**-0.50 (0.04)****
ΔlnENERGY	0.008 (0.50)	0.45 (0.13)	-	2.85 (0.13)	-0.009 (0.10)	-2.99 (0.27)	**-0.72 (0.00)***
ΔlnDEP	0.0025 (0.09)***	-0.09 (0.01)*	0.013 (0.58)	-	-0.001 (0.13)	1.40 (0.00)*	**-0.22 (0.27)**
ΔlnFDI	0.47 (0.19)	-6.87 (0.46)	-3.36 (0.54)	-81.74 (0.13)	-	124.96 (0.11)	**-0.93 (0.00)***
ΔURBAN	-0.0018 (0.08)***	0.071 (0.00)*	-0.0045 (0.78)	0.68 (0.00)*	0.00087 (0.11)	-	**-0.19 (0.33)**
Indonesia	**ΔlnCN**	**ΔlnGDP**	**ΔlnENERGY**	**ΔlnDEP**	**ΔlnFDI**	**ΔURBAN**	**ECT**

ΔlnCN	-	3.85 (0.017)**	0.10 (0.95)	10.25 (0.53)	-0.008 (0.72)	-6.18 (0.52)	-1.15 (0.00)*
ΔlnGDP	0.049 (0.00)*	-	0.41 (0.04)**	1.46 (0.45)	0.006 (0.02)**	-0.11 (0.92)	-0.41 (0.01)**
ΔlnENERGY	-0.004 (0.72)	0.32 (0.01)**	-	-2.14 (0.10)	0.004 (0.07)***	1.69 (0.02)**	-1.22 (0.00)*
ΔlnDEP	-3.40 (0.98)	0.046 (0.07)***	-0.04 (0.09)***	-	0.00031 (0.37)	0.55 (0.00)*	-0.16 (0.34)
ΔlnFDI	-1.18 (0.34)	33.82 (0.01)*	-2.62 (0.85)	101.83 (0.42)	-	-93.75 (0.20)	-0.59 (0.00)*
ΔURBAN	-0.00033 (0.92)	-0.063 (0.13)	0.12 (0.01)*	1.64 (0.00)*	-0.0010 (0.09)***	-	-0.33 (0.10)
Nigeria	ΔlnCN	ΔlnGDP	ΔlnENERGY	ΔlnDEP	ΔlnFDI	ΔURBAN	ECT
ΔlnCN	-	0.30 (0.73)	0.62 (0.34)	-14.34 (0.43)	0.0089 (0.36)	19.36 (0.43)	-0.50 (0.03)**
ΔlnGDP	0.025 (0.53)	-	-0.04 (0.75)	-7.31 (0.00)*	-0.0006 (0.72)	11.17 (0.00)*	-0.83 (0.00)*
ΔlnENERGY	0.06 (0.38)	-0.14 (0.64)	-	-5.34 (0.28)	-0.0007 (0.81)	6.99 (0.31)	-0.33 (0.22)
ΔlnDEP	0.0034 (0.28)	-0.04 (0.00)*	-0.0078 (0.41)	-	-7.41 (0.57)	1.38 (0.00)*	-0.41 (0.04)**
ΔlnFDI	-8.76 (0.08)***	-19.07 (0.29)	1.02 (0.93)	-101.1 (0.72)	-	160.20 (0.68)	-0.86 (0.00)*
ΔURBAN	-0.0024 (0.28)	0.034 (0.00)*	0.0050 (0.46)	0.71 (0.00)*	4.96 (0.60)		-0.46 (0.03)**
Saudi Arabia	ΔlnCN	ΔlnGDP	ΔlnENERGY	ΔlnDEP	ΔlnFDI	ΔURBAN	ECT
ΔlnCN	-	15.36 (0.47)	45.21 (0.005)*	10.94 (0.87)	0.005 (0.97)	-32.96 (0.54)	-0.45 (0.02)**
ΔlnGDP	0.0006 (0.72)	-	0.21 (0.17)	0.21 (0.71)	0.0013 (0.35)	0.22 (0.95)	-0.54 (0.00)**
ΔlnENERGY	0.0046 (0.01)**	0.31 (0.17)	-	-0.77 (0.24)	-0.002 (0.13)	12.03 (0.01)**	-1.03 (0.00)*
ΔlnDEP	0.00058 (0.35)	0.19 (0.01)*	-0.10 (0.04)**	-	-0.00012 (0.79)	7.19 (0.00)*	-0.59 (0.00)*
ΔlnFDI	-0.18 (0.53)	8.74 (0.76)	16.30 (0.51)	61.39 (0.50)	-	-609.25 (0.41)	-0.24 (0.21)
ΔURBAN	-9.69 (0.19)	-0.020 (0.04)**	0.019 (0.00)*	0.11 (0.00)*	3.90 (0.51)	-	-0.75 (0.00)*
Venezuela	ΔlnCN	ΔlnGDP	ΔlnENERGY	ΔlnDEP	ΔlnFDI	ΔURBAN	ECT
ΔlnCN	-	6.34 (0.80)	42.10 (0.004)*	15.35 (0.86)	0.002 (0.98)	-37.75 (0.45)	-0.43 (0.04)**
ΔlnGDP	-0.01 (0.15)	-	0.52 (0.00)*	0.83 (0.39)	-0.0006 (0.79)	-4.09 (0.50)	-0.85 (0.00)*
ΔlnENERGY	0.007 (0.23)	0.32 (0.03)**	-	-0.56 (0.48)	0.0016 (0.44)	5.10 (0.32)	-1.37 (0.00)*
ΔlnDEP	-0.00033 (0.85)	0.044 (0.36)	-0.0024 (0.94)	-	-0.00030 (0.62)	5.28 (0.00)*	-0.08 (0.45)
ΔlnFDI	-0.04 (0.93)	13.58 (0.33)	-3.87 (0.75)	-95.74 (0.22)	-	676.25 (0.17)	-0.67 (0.00)*
ΔURBAN	0.00017 (0.53)	-0.006 (0.38)	0.0012 (0.83)	0.13 (0.00)*	5.97 (0.53)	-	-0.15 (0.19)

The main aim of this section is to determine the adjustment capacity of each variable for each OPEC countries and measure the speed that returns to the equilibrium in the long-run. However, one can deduce the short-term causality relationship. Indeed, the results in Table 5 indicate a bidirectional causal relationship between GDP per capita and CO_2 emissions per capita and a unidirectional relationship in which per capita GDP positively affects energy consumption in Algeria. In Nigeria, there is no causal relationship between CO_2 emissions, GDP per capita and energy consumption. In the case of Indonesia, there is a bidirectional relationship between GDP per capita and CO_2 emissions, but there is no relationship between energy consumption and CO_2 emissions. There also exists a positive unidirectional causality of GDP to energy consumption. In Saudi Arabia there is a positive bidirectional causal relationship between energy consumption and CO_2 emissions. In the short term in Venezuela, there is a bidirectional causal relationship between GDP per capita and energy consumption, and a unidirectional causal relationship of CO_2 to energy. The short-term casual relationship between GDP per capita, energy consumption and CO_2 emissions per capita in the 5 countries of OPEC are diversified, which is proof of the heterogeneity of these countries.

The existence of long-term causal relationship is determined by the correction term ECT errors. When it is significant and negative, it indicates that there is at least one long-term relationship between the variables and the endogenous variable plays an important role of adjustment factor when the system deviates from equilibrium (Farhani and Ben Rejeb, 2012). The results in Table 6 show that GDP per capita, CO_2 emissions and energy consumption are factors for adjustments in Algeria and the speed of adjustment is 0.50%, 0.69% and 0.72% per year, respectively. In Indonesia, GDP per capita with a rate of 0.41%, CO_2 emissions per capita with a rate of 1.15%, and energy consumption per capita with a rate of 1.22% are the long-term adjustment factors towards equilibrium. Economic growth and CO_2 emissions are the adjustment factors to Nigeria with 0.83% and 0.50% respectively of speed of adjustment. Energy (1.03%), CO_2 (0.45%) and GDP (0.54%) serve as adjustment variables in Saudi Arabia. In Venezuela, GDP per capita, energy consumption and CO_2 emissions are the adjustment factors with 0.85%, 1.37% and 0.43% as respective velocities.

5.4. The results of long-term causal relationships (DOLS and FMOLS)

To determine the relationship between these variables, we estimated the model (8) to (10) by ordinary least squares (OLS) but also by FMOLS and DOLS methods. The OLS estimate of a model or the cointegrated variables do not provide the convergent coefficients because of the problem of endogeneity. The methods FMOLS and DOLS allow taking into account the endogeneity of regressors and autocorrelation. This allows for obtaining the consistent estimators, even with small sample sizes. Here we estimate long-term relationships between GDP per capita, energy consumption per capita and CO_2 emissions per capita for each country individually. We consider each of the variables (GDP, energy and CO_2) as an endogenous variable and determine the intensity and significance of the influence of other system variables (GDP, energy, CO_2 emissions). The results are noted in Table 6 for GDP per capita, energy consumption per capita and CO_2 emissions per capita.

First, the table below gives the results of estimating the long-term causal relationships of the energy, the GDP and the CO_2. In Algeria, the hypothesis of neutrality is verified between GDP and CO_2; the coefficient of GDP is not significant. In other countries, GDP per capita has a significantly positive effect on CO_2. Increasing the GDP per capita of 1% increase the CO_2 more than 3% in Indonesia, more than 15% in Nigeria, 27% in Venezuela, and 30% in Saudi Arabia. In a unanimous way, estimates indicate that energy has a significantly positive impact on CO_2 in the four countries: Algeria, Indonesia, Nigeria and Saudi Arabia. But energy is not significant on CO_2 emissions in Venezuela. In fact, a 1% increase in energy consumption increases the CO_2 emissions by 4.73% in Algeria, 0.68% in Nigeria and 4.60% in Indonesia.

Table 6

Causal relationship of long-term in the OPEC countries

Dependent variable = lnNC						
	lnGDP			**lnENERGY**		
Countries	**OLS**	**DOLS**	**FMOLS**	**OLS**	**DOLS**	**FMOLS**
Algeria	-1.92 (0.62)	-12.54 (0.70)	-5.23 (0.22)	3.38 (0.25)	12.84 (0.92)	4.73 (0.09)***
Indonesia	3.46 (0.01)**	-14.16 (0.65)	3.27 (0.00)*	-4.22 (0.03) **	-57.95 (0.10)	4.60 (0.00)*
Nigeria	-1.42 (0.17)	15.33 (0.27)	-1.14 (0.07)***	0.78 (0.20)	-8.95 (0.41)	0.68 (0.05)**
Saudi Arabia	26.01 (0.07)***	-438.74 (0.06)***	30.22 (0.06)***	28.83 (0.12)	343.44 (0.05)**	18.17 (0.38)
Venezuela	19.41 (0.16)	-203.26 (0.04)**	27.25 (0.07)***	29.27 (0.11)	-63.15 (0.48)	16.27 (0.41)
Dependent variable = lnGDP						
	lnNC			**lnENERGY**		
Countries	**OLS**	**DOLS**	**FMOLS**	**OLS**	**DOLS**	**FMOLS**
Algeria	-0.006 (0.62)	-0.07 (0.35)	-0.006 (0.41)	0.61 (0.00)*	1.46 (0.73)	0.64 (0.00)*
Indonesia	0.076 (0.01)*	0.23 (0.02)**	0.081 (0.00)*	0.33 (0.27)	4.36 (0.01)*	0.17 (0.55)
Nigeria	-0.06 (0.17)	-0.02 (0.25)	-0.06 (0.02)**	1.82 (0.00)*	0.50 (0.00)*	0.50 (0.00)*
Saudi Arabia	0.52 (0.06)***	0.01 (0.10)	0.006 (0.02)**	0.005 (0.07)***	0.41 (0.45)	0.61 (0.01)*
Venezuela	-0.027 (0.01)*	0.007 (0.82)	-0.02 (0.00)*	1.06 (0.00)*	3.58 (0.12)	1.08 (0.00)*
Dependent variable = lnENERGY						
	lnGDP			**lnNC**		
Countries	**OLS**	**DOLS**	**FMOLS**	**OLS**	**DOLS**	**FMOLS**
Algeria	1.07 (0.00)*	3.90 (0.01)*	1.10 (0.00)*	0.019 (0.25)	0.45 (0.03)**	0.018 (0.05)**
Indonesia	0.17 (0.27)	4.70 (0.09)***	0.17 (0.11)	-0.05 (0.03)**	-0.13 (0.47)	-0.05 (0.00)*
Nigeria	1.45 (0.00)*	-3.14 (0.18)	1.53 (0.00)*	0.098 (0.20)	0.27 (0.43)	0.11 (0.02)**
Saudi Arabia	0.31 (0.06)***	5.06 (0.02)**	0.29 (0.00)*	0.003 (0.12)	-0.01 (0.33)	0.004 (0.00)*
Venezuela	0.51 (0.00)*	1.24 (0.01)*	0.51 (0.00)*	0.0079 (0.32)	0.37 (0.00)*	0.007 (0.04)**

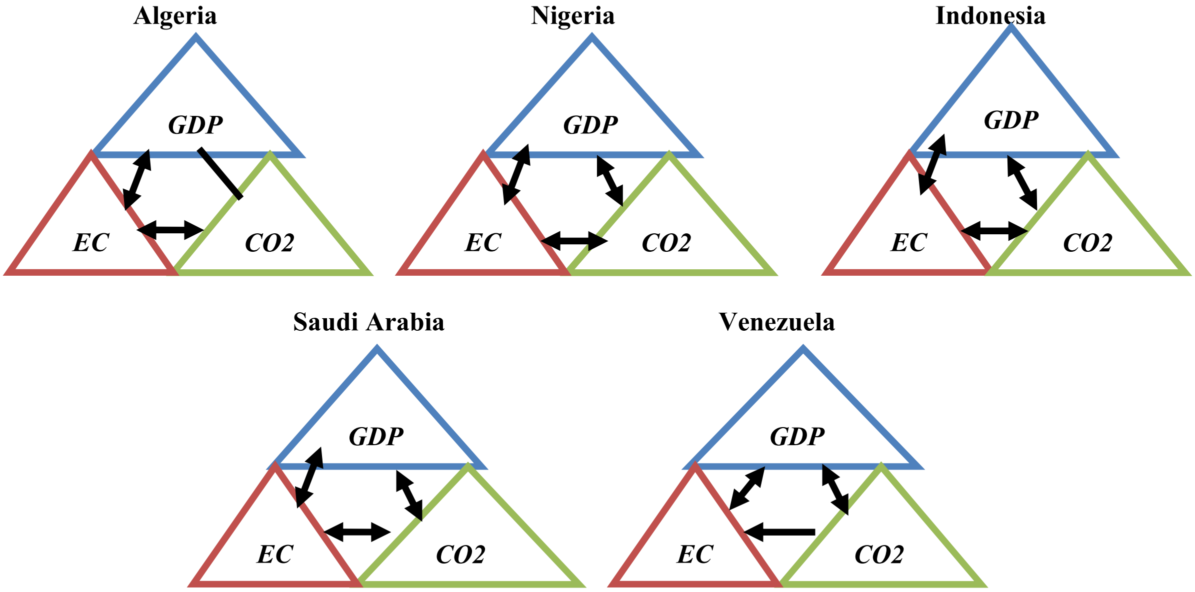
<u>Notes:</u> (*), (**) and (***) indicate the significance levels at the 1%, 5% and 10% respectively. OLS = Ordinary Least square. DOLS = Dynamic Ordinary Least Square and FMOLS = Fully Modified Ordinary Least Square. lnENERGY = logarithm of the energy consumption, lnNC = logarithm of the emission of CO_2 and lnGDP = logarithm of GDP per capita.

Second, the growth hypothesis is verified for all countries where energy consumption has a significant positive effect on GDP per capita. This implies that energy plays a critical role in the production process, and it is complementary factor of production process like capital and labor. The CO_2 emissions have a significant negative effect on GDP per capita in Nigeria and Venezuela. This implies an increase in CO_2 emissions reduced per capita GDP. However, in Saudi Arabia and Indonesia, CO_2 emissions positively affect GDP. For Algeria CO_2 emissions has no significant impact on GDP.

Finally, the conservation hypothesis is also verified for all OPEC countries. There is a unidirectional causality running from economic growth to energy consumption. The increase in per capita GDP of 1% leads to an increase in energy consumption around 4% in Algeria, nearly 5% in Indonesia, 1.5% in Nigeria, 5% in Saudi Arabia and 1.24% in Venezuela. It is also revealed that CO_2 emissions affect energy consumption in these countries. Indeed, the FMOLS estimators and DOLS estimators provide statistically significant coefficients for energy consumption for each of the OPEC countries. We can now synthetically set the triangles of causality between GDP per capita, energy consumption per capita and CO_2 emissions per capita for the five OPEC countries.

Figure 1

Triangles of causality relationship between GDP, energy use and CO_2 emissions



***<u>Notes:</u>* ↔ Bidirectional causality; → unidirectional causality; — No causality**

5. Conclusion and policy implications

The main goal of this study is to examine the relationship among environmental quality, GDP and energy use in five OPEC countries. To achieve our goal, we have used annual data of 25 years from 1990 to 2014 and adopted a multi-step procedure, stationarity tests to DOLS estimates and FMOLS through the cointegration tests and the long term determination of adjustment speeds by VECM estimates.

The unit root tests of ADF and PP have shown that the series of GDP per capita, energy consumption, CO_2 emissions per capita, FDI, density of population and urbanization are not stationary in levels. However, their first difference is stationary. These series are integrated of the same order 1 in each OPEC countries. In addition, we used the cointegration tests of Johansen. The test results indicate rejection of the null hypothesis of no cointegration relationships. It exists in every country implying that at least one long-term relationship exists between the GDP, energy and CO_2 series. The series of GDP, energy and CO_2 are integrated of the same order and cointegrated; it is possible to determine the short-term causality through a VECM. Estimates by VECM for each country, has enabled us to confirm the existence of long-term causal relationships and calculate the adjustment speeds when the system deviates from its long-term path through the significance and the sign of the error correction term. To determine the direction and influence intensity of the series on each other, we applied the FMOLS and DOLS methods of estimation. These approaches are adapted to correct the endogeneity of regressors and the problem of autocorrelation and to have consistent estimators, which is not always the case for OLS. The results show that in the long-run there are two-way causal relationships between GDP and energy consumption for all countries. That is, feedback hypothesis is established in these countries. Bilateral causal relationship between GDP and CO_2 emissions are also observed in all countries except Algeria where no causality is found. The same relationship between energy consumption and CO_2 emissions is also observed in all countries with an exception for Venezuela where unidirectional causality running from CO_2 emissions to energy consumption is found.

To continue growth with the quality environment our findings have the following significant policy implications: (1) Realizing real energy transition by playing the comparative advantages mechanism. (2) Promoting a healthy environment and managing concerted and sustainable natural resources. (3) Adopting energy efficient methods and principles to reduce CO_2 emissions without compromising competitiveness to maintain a healthy environment for long term sustainable growth. Therefore, efforts should be made to encourage industries to adopt new technologies to minimize pollution complying the recommendations of the post-Kyoto Protocol. The policies that focus on the reduction of emissions must focus on the adjustment of industrial structure and increased energy efficiency. This can be achieved through advances in technology, investment in energy saving devices by adjusting the energy structure (based on renewable energy) and increasing the public awareness via campaign and advertisement. The governments and public sector must work together to achieve a long term sustainable economic growth.

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