Relationship between Renewable Energy Consumption, CO_2 Emissions and Oil Prices in Industrial Sector of Selected OPEC and Non-OPEC Countries

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ABSTRACT

Considering global warming and importance of sustainable growth in economic sub-sectors, this paper presents and estimates an empirical model of renewable energy consumption for the industrial sector of selected OPEC and non-OPEC countries over the period 1990-2014. Panel co-integration estimates by Pedroni (1999,2004) and Westerlund (2005,2006) show that, in the long term, increases in industrial value added per capita, real oil prices, and CO_2 per capita are found to be major drivers behind per capita renewable energy consumption for both OPEC and Non-OPEC nations. Panel Granger causality by the Dumitrescu and Hurlin (2012) method confirms that there are bi-directional causality relationship between research variables and therefore verify feedback hypothesis. Finally, FMOLS and DOLS results show that when industrial value added per person increases, per capital renewable energy consumption increases by greater magnitude in non-OPEC than OPEC countries; also an increase in CO_2 emissions per person increases per capita renewable energy consumption by greater amount in non-OPEC than OPEC nations.

1. Introduction

Dependency of economic growth on energy consumption especially fossil fuels, through its release of carbon dioxide (CO_2) into the atmosphere, is the main driver behind global warming . Traditional energy sources like oil, natural gas and coal are considered to be the most effective drivers of economic growth (Ellabban et. al., 2014). Historically, countries would intend to have higher economic growth and energy is one factor in production function playing a key role in economic growth. Industrial productions are responsible for almost 50% of global energy consumption and 36% of greenhouse gas emissions (Yang and Zhao, 2014). During the period 1975-2005, total energy consumption in the indust rial sector grew by 65% (IEA, 2017). Also, during the period 2010-2040, energy consumption in this sector is expected to be increased by 65% (Sieminski, 2014). The IEA (2017) reports that greenhouse gas emissions in the industrial sector will grow by about 1.7 times until 2030. In particular, given the dominance of fossil fuels in the macro economy of OPEC and non-OPEC countries, increasing energy demand in these countries would result in higher greenhouse gas (GHGs) emissions overtime(Adetutu, 2014). Nowadays, energy independence and security of supply, energy price shocks, non-renewable features of oil and natural gas as traditional energy sources, and global warming are considered the most fundamental global issues (Sadorsky, 2009a). This would cause emerging a wide range of solutions to combat these issues. It is expected that around 39% increases in electricity production will be generated from renewable sources by 2050 (IEA, 2017). Thus, it is emphasized that 50% of global CO_2 emissions can be reduced and the increase in global temperature can be limited to the range of 2.0–2.4°C (Koçak and Şarkgüneşi, 2017). In recent years, the production and consumption of renewable energies have increased, and

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[1] The Intergovernmental Panel on Climate Change (IPCC), 2007.

therefore, renewable energies become important factor of economic growth. Currently, renewable energy makes up a relatively small portion of the overall energy mix in oil-rich countries compared with other nations. In 2014, for example, renewable energy (hydro, biomass, wind, geothermal, solar, and tidal) accounted for 19.2% of primary world energy use (RENEWABLES, 2016). According to the IEA Renewable Energy, Medium-Term Market Report 2017, the same share of renewable energy is expected to reach at least to 26% in 2020.

In 2014, the share of industrial value added in world GDP was 27% and OECD share of industrial value added was 24% of GDP. The share of industrial value added in selected OPEC and Non-OPEC countries was higher than 47% and 29%, respectively (Adetutu, 2014). It is obvious that the selected OPEC and Non-OPEC countries have a greater share of industrial value added share in GDP that is higher than the world average. So the industrial sector plays a great role in GDP of oil-rich countries and moving toward industrialization can lead to higher economic growth for these countries. Comprising a third of the total global energy demand, the industrial sector is a crucial end-use sector that must be engaged to achieve a doubling of the share of renewable energy. Achieving higher penetration levels for renewable energy will be crucial to achieving higher long-term reductions in industry sector's fossil fuel demand and related CO_2 emissions. Substituting renewable energies with fossil fuels in industrial sector would help to decrease GHG emissions. Therefore, accelerated action will be required in all regions and industrial sub-sectors to achieve this goal (IRENA, 2015).

The relationship between energy consumption and economic growth has been extensively investigated. In the IEA's economic models, the growth rate of GDP is the main driver of the demand for energy (IEA, 2017); and consequently, renewable energy consumption should be a function of GDP. This article utilizes the industrial productions as a proxy of GDP in industrial sector. It is expected that increases in industrial productions lead to an increase in the consumption of renewable energy. In 2016, fossil fuels accounted for 81% of world energy demand; and in particular, oil accounted for 31.7% of world energy demand (IEA, 2017). In this paper, renewable energy is considered to be a substitute for oil; thereby, oil price is the price of a substitute product for renewable energy. Rising oil prices is expected to encourage industrial producers to reduce oil consumption, purchase more efficient products, and switch to use renewable energy in production process. In addition, global warming issues have put CO2 emissions into the energy policy spot light. Any serious attempt to deal with global warming is going to reduce dependency on fossil fuels. Consequently, increases in carbon dioxide emissions, coupled with increased concern over global warming, is likely to lead to increase consumption of renewable energy. Therefore, this study aims to explore the relationship between renewable energy consumption, oil prices, CO2 emissions, and industrial value added for selected OPEC and non-OPEC countries over the period 1990- 2014. The selection of industrial sector of oil-rich countries is due to large share of this sector in energy consumption and its key role in economies of oil-rich countries. . More importantly, using renewable energy in industrial sector can help to make new jobs, protect environment and conserve natural resources to future generation, while diversifying energy sources that increases a country's energy independence and security (Dincer, 2000). The promotion of renewable energy has a positive macroeconomic impact on improving growth , promoting employment , enhancing sustainable development (Del Rio and Burguillo, 2009), increasing and improving energy access, particularly, in remote rural areas , and attracting more high-skilled human capital to enjoy the benefits of renewable energy.

Contribution and importance of this paper comes from two points. First, the most studies addressed the problem of this research paper at national-level and across countries; this does not give a clear view to policy makers to understand renewable energy consumption at sectoral levels. Therefore, this study seeks to address the renewable energy consumption differences among the industrial sectors of selected OPEC relative to non-OPEC countries, which has not been addressed in available literature. For this reason, the outcomes of this study would provide valuable inferences for economic growth, energy security and global warming. Second, this study applies panels of OPEC and Non-OPEC countries that are largely heterogeneous (Bhattacharya, et al, 2016); taking this into consideration, this paper explores causality relation between renewable energy consumption and industrial production using heterogeneous panel causality estimation techniques developed by Dumitrescu and Hurlin (2012). However, to the best of our knowledge, it seems there is a research gap in the literature in terms of relationship between renewable energy and sectoral level growth in OPEC and non-OPEC countries. This study intends to fill this gap in the literature.

The remainder of the paper is organized as follows: Section 2 reviews literature on the renewable energy and economic growth relationship. Section 3 describes data and research model variables. Section 4 presents theoretical and empirical methodologies. Section 5 provides empirical results and discussions. Section 6 concludes the paper and provides some policy recommendations based on main the research findings.

[2] OPEC Speech delivered by Mohammed Barkindo, Acting for the OPEC Secretary General, at the Sixth Russian Oil & Gas Week, Moscow, Russia, 30 October-2 November 2006.

2. Literature review

The most of previous studies have focused on the relationship between energy consumption and output or income that can be divided into four groups with mixed results. The first group of studies found the causality relationship running from energy consumption to GDP that confirm the growth hypothesis inferring that the economic growth is energy dependent and energy supply crisis is sensitive to economic growth (e.g., Bilgili, 2015; Bilgili and Ozturk, 2015; Ozturk and Bilgili, 2015; Ozturk and Bilgili, 2015; Inglesi-Lotz, 2016; Hamit-Haggar, 2016; Alper and Ocal, 2016). The second group of studies verified a unidirectional causality relationship running from GDP to energy consumption that supports the conservative hypothesis. This hypothesis is opposed to the growth hypothesis indicating that conservative energy policy does not harm production (e.g., Sadorsky, 2009a; Tiwari, 2011; Al-mulali et al., 2013; Tugcu et al., 2012; Alper and Ocal, 2016). The third group of studies found the bidirectional Granger causality of energy consumption with income approving the feedback hypothesis (e.g., Apergis and Payne, 2010; Apergis and Payne, 2011; Apergis and Payne, 2012; Salim and Rafiq, 2012; Al-mulali et al., 2013; Al-mulali et al., 2014; Shahbaz et al., 2016; Pao and Fu, 2013; Lin and Moubarak, 2014; Shahbaz et al., 2015).. The fourth group of studies claim that energy consumption is independent of GDP that confirm the neutrality hypothesis, it means that there is not causality between real GDP and energy consumption and both are independent. The advocates of this hypothesis believe that energy consumption has no influence on economic growth; and the economy can adjust eco-friendly energy policies to protect against environmental pollution, these policies may include the imposition of carbon tax and/or subsidies on energy consumption and encourage the use of green technology in industrial production to keep pollution at a minimum level.

However, in particular, many researchers have studied to examine the relationship between economic growth, renewable energy consumption and CO_2 emissions. The Results from these studies are different depending on variation of selected country factors, and chosen structure of the economy, energy type chosen, period of analysis and methodologies. Some of these related studies are cited below:

Sadrosky(2009a), estimates an empirical model of renewable energy consumption for the G7 countries. The results show that in the long term, increases in real GDP per capita and CO_2 per capita are found to be major drivers behind per capita renewable energy consumption. The results are robust across two different panel cointegration estimators. Also, oil price increase has a smaller but negative impact on renewable energy consumption.

Kulionis (2013), utilizes a multivariate framework to test the causal relationship between renewable energy consumption, gross domestic product (GDP) and carbon dioxide (CO_2) emissions in Denmark using annual data from 1972-2012. The results of cointegration analysis following Johansen (1992) approach show that there is no evidence of cointegration among the test variables. The empirical results from Granger causality Toda Yomamoto test and Granger causality test using rst differences strongly supports a unidirectional causality coming from renewable energy consumption to CO_2 emissions. The results also indicate that there is no statistically significant causality between the economic growth and renewable energy consumption and also between economic growth and CO_2 emissions.

Zoundi (2017) combine a panel cointegration analysis with a set of robustness tests to assess the short and long-run impacts of renewable energy on CO_2 emissions, as well as the Kuznets Environmental Curve hypothesis for 25 selected African countries, over the period 1980-2012. The results provided no evidence of a total validation of EKC predictions. However, CO_2 emissions are found to increase with income per capita. The overall estimations strongly revealed that renewable energy, with a negative effect on CO_2 emissions, coupled with an increasing long-run effect, remains an efficient substitute for the conventional fossil-fuelled energy.

Isic et al. (2017) examine the relationships between tourism development, renewable energy consumption, and economic growth in the United States, France, Spain, China, Italy, Turkey, and Germany using an innovative bootstrap panel Granger causality model. The results show that tourism development and economic growth are interdependent in Germany; whereas tourism development induces economic growth in China and Turkey, the reverse is true in Spain. Causal relationships between renewable energy and economic growth give credence to theories of renewable energy-led growth in Spain and growth-led renewable energy in China, Turkey, and Germany. Whereas the Italian and U.S. models demonstrated a bidirectional relationship, the Spanish, Italian, Turkish, and U.S. data show a causal link stemming from tourism development. Theoretical and policy implications are discussed within the realm of macroeconomics and sustainability.

According to the literature and to the best of our knowledge, there is lack of study to look at a causal-effect relationship between the renewable energy consumption and industrial level value added for a panel of OPEC and OPEC member countries; this paper seeks to fill this research gap and help to improve

[3] Squalli, 2007; Apergis and Payne, 2010; Ozturk, 2010; Inglesi-Lotz, 2016
[4] Hillebrand et al, 2006; Moreno and Lopez, 2008; Apergis and Salim, 2015
[5] Maiga et al, 2008; Zand and Kimber, 2009; Thiam, 2011

Table 1- Literature on the relationship between renewable energy consumption and economic growthAuthor (s) Region Period Methodology Conclusion

Author (s)	Region	Period	Methodology	Conclusion
Payne (2009)	USA	1949–2006	Toda-Yamamoto	neutrality
Sadorsky (2009b)	18 emerging countries	1994–2003	Panel co-integration, panel DOLS, panel FMOLS, panel VEC	conservation
Apergis and Payne (2010)	20 OECD countries	1985–2005	Panel co-integration, panel FMOLS, panel VEC	feedback
Menegaki (2011)	27 European countries	1997–2007	One-way random effect mod- el, Panel Causality Tests.	neutrality
Apergis and Payne (2011)	6 Central Ameri- can countries	1980–2006	Panel co-integration, panel FMOLS, panel VEC	feedback
Tiwari (2011))	India	1960–2009	Structural VAR	conservation
Tugcu et al. (2012)	G7 countries	1980–2009	Co-integration and Hatemi-J causality	Mix results
Salim and Rafiq (2012)	6 major emerg- ing economies	1980–2006	Panel co-integration, panel DOLS, panel FMOLS, Granger causality (short-run)	feedback
Apergis and Payne(2012)	80 countries	1990–2007	co-integration and VEC	feedback
Pao and Fu (2013)	Brazil	1980–2010	co-integration and VEC	feedback
Ocal and Alper (2013)	Turkey	1990–2010	Co-integration and Toda-Yamamoto	neutrality
Al-mulali et al. (2013)	High, upper-middle, lower middle and low income countries	Different periods	FMOLS	Feedback, Neutrality and Conservation
Aslan (2014)	United States	1961–2011	ARDL bounds testing approach	growth
Lin and Mou- barak (2014)	China	1977–2011	ARDL bounds testing approach; Johansen	feedback
Al-mulali et al. (2014)	18 Latin Ameri- can countries	1980–2010	cointegration techniques.	feedback
Bilgili (2015)	USA	1981–2013	Panel co-integration, panel DOLS, panel VEC	growth
Shahbaz et al. (2015)	Pakistan	1972Q1– 2011Q4	wavelet coherence	feedback
Dogan (2015)	Turkey	1990–2012	Co-integration and VEC	neutrality
Bilgili and Oz- turk (2015)	G7 countries	1980–2009	Co-integration and VEC	growth
Ozturk and Bil- gili (2015)	51 Sub-Sahara African countries	1980–2009	Panel co-integration, panel OLS and panel DOLS	growth
Destek (2016)	Brazil, India, Turkey, South Africa, Mexico and Malaysia	1971–2011	Panel co-integration, panel OLS and panel DOLS	conversation and the neutrality
Alper and Ocal (2016)	New EU mem- ber 7 countries	1990–2009	The asymmetric causality approach	Mix results
Shahbaz et al. (2016)	BRICS countries	1991Q1– 2015Q4.	Co-integration and Hatemi-J causality	feedback
Inglesi-Lotz (2016)	34 OECD countries	1990–2010	Panel co-integration, fixed effect and panel VEC	growth
Hamit-Haggar (2016)	11 Sub-Saharan African countries	1971–2007	Panel co-integration, fixed ef- fect and pooled estimation	growth
Bhattacharya et al. (2016)	38 top renewable energy countries	1991–2012	Panel co-integration, panel FMOLS, DOLS and Dumitrescu-Hurlin	neutrality
Koçak and Şarkgüneşi (2017)	Balkan countries 9 Black Sea and	1990 –2012	panel co-integration and co-integration and Dumitrescu and Hurlin (2012) panel causality	growth, feedback and neutrality hypotheses

literature on this subject matter. In contrast to the literature, this paper also presents a cause and effect relationship between renewable energy consumption, per capita CO2 emissions, industrial productions, and oil price using a heterogeneous panel for both OPEC and Non-OPEC members.

3. Data and Research Variables

This study employs annual data for a selected OPEC and non-OPEC countries covering the period 1990 to 2014. This particular period has been chosen simply because the required data are not available for earlier periods for all selected countries. The non-OPEC countries chosen in this study are some oil rich countries to compare with the selected OPEC countries. In order to account for changes in variables attributable to changes in population structure (population growth), all variables have been transformed to per capita basis. The variables considered in the study are as follows: IVA is industrial value added per capita indicating a GDP indicator for industrial production sector for each country; IVA time series are PPP adjusted in constant 2010 US dollars. REC represents renewable energy consumption per capita measured in metric tons. CO2 is an indicator of emissions per capita that is measured in metric tons. The data on these variables are obtained from World Bank open data base. ROP is real oil price that is measured using the spot price on West Texas Intermediate (WTI) crude oil in constant 2010 US dollars based on data available from BP Statistical Review of World Energy (2017). WTI has a long history being used as a benchmark for oil prices. The panel of selected OPEC and non-OPEC countries are a natural panel; because they share common economic and political attributes (i.e., each country in OPEC is developing, and the most of them are poor and non-democratic nations, but non-OPEC countries are developed, wealthy and democratic) ; and consequently, likely each group share some common growth rates in variables as a panel.

Figure 1 and Figure 2 show the variables trends for selected OPEC and non-OPEC countries, respectively over time.

Renewable energy consumption (i.e., net geothermal, solar, wind, wood and waste electric power consumption) is as percentage of primary energy consumption, which is scaled by 10 units. Industrial value added is scaled by 1000 units. According to Figure 1, industrial value added per capita has increased after year 2000 followed by increasing real oil prices. Also, CO2 emissions per capita have increased smoothly since the early 2000s. Renewable energy consumption has had a low and flat trend in the sample period. As we can see, except renewable energy consumption, other variables have increasing trends in OPEC countries especially after the early 2000s. Also, as we can notice in Figure 2, industrial value added per capita has increased in moderate rate over time for selected non-OPEC countries; CO2 emissions per capita after some unstable and smoothing movements, it is decreasing toward end of the study period inn non-OPEC countries. Similar to OPEC, renewable energy consumption has relatively low and smoothing trend for non-OPEC nations over time, showing important role of non-renewable energies compared with renewable energies in oil rich countries.

4. Methodology

4.1. The model

Given the growing recognition of renewable energy in establishing a more sustainable energy consumption mix, recent studies (e.g., Sadorsky, 2009a; Payne, 2012; Salim and Rafiq, 2012) have analyzed the determinants of renewable energy consumption within a demand modeling framework. As is standard in energy consumption models, industrial productions is included in the demand model measured using per capita 2010 US dollars. In a different context, Majum-dar and Parikh (1996) use oil prices and

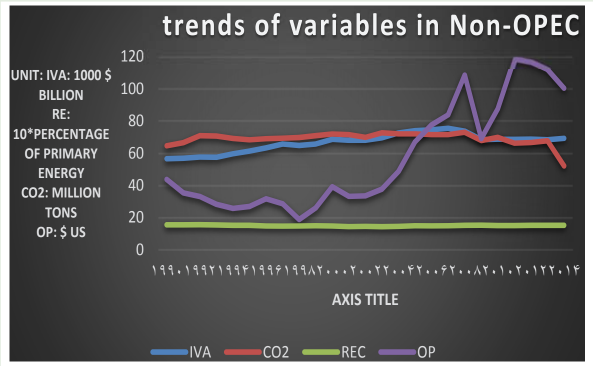

Figure 1: Trends of Industrial Value Added, CO2 Emissions, Renewable Energy Consumption and Real Oil Prices in Selected OPEC countries during 1990 to 2014.

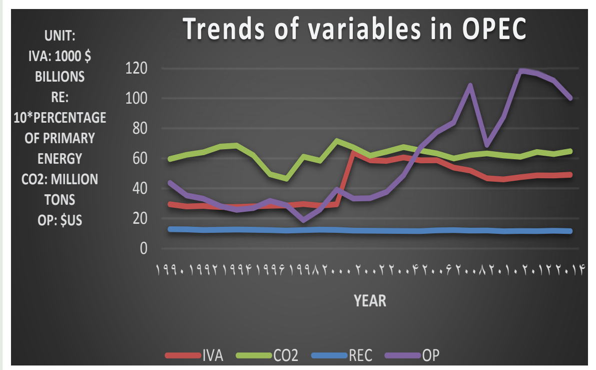

Figure 2: Trends of Industrial Value Added, CO2 Emissions, Renewable Energy Consumption and Real Oil Prices in selected Non- OPEC countries during 1990-2014. Source: Authors' findings

6 For instance, see Payne, (2009); Ocal and Alper (2013); Dogan (2015); Menegaki (2011); Alper and Ocal (2016); Rahman et al (2016).
7 The selected OPEC countries are Algeria, Iran, Iraq, Saudi Arabia, UAE, Venezuela, Ecuador, Libya, and Nigeria.
8 The selected non-OPEC countries as industrialized oil rich countries include USA, UK, Norway, Canada, Brazil, Russia, and Mexico
9 Sari et al (2008)

population to model the demand for energy in India; and Silk and Joust (1997) use oil prices to model residential energy demand in the United States(Sadorsky, 2009 a,b). In accordance with societal concerns over global warming, per capita CO_2 emissions is included as an important additional explanatory variable affecting renewable energy consumption. Finally, we follow Sadorsky (2009a); Salim and Rafiq(2012); and Apergis and Payne(2017) to specify a demand model for renewable energy consumption per capita (REC) as a function of industrial value added per capita(IVA), CO_2 emissions per capita (CO_2), and oil price (ROP) in general form as follows below :

$$REC=f(IVA,CO2,ROP) \quad (1)$$

Given the respective variables are integrated of order one, we examine panel co-integration test by Pedroni (1999, 2004) and also consider possible structural breaks following Westerlund (2005,2006). Eq. (1) is specified in log-log form (natural logs denoted in lower case letters) within a panel regression framework as:

$$LREC_{it}=\beta_{0it}+\beta_{1it}LCO_{2it}+\beta_{2it}LIVA_{it}+\beta_{3it}LOP_{it}+u_{it} \quad i=1,\ldots,N \text{ and } t=1,\ldots,T \quad (2)$$

β_0,β_1, $\beta_2$and β_3 are the parameters of the model to be estimated, and uit is the residuals.

4.2. Econometric methodology

This paper uses panel modeling approach in three steps. First, we apply panel unit root tests to find the order of integration of the model variables. Second, if the model variables are non-stationary, then the next step is to test whether there is a panel co-integration between the variables using Pedroni (1999, 2001, 2004) and Westerlund (2005, 2006). When the series are integrated of order one, one of more linear combinations might exist between variables that such series are called panel co-integrated. If panel co-integration is found, the next step is to investigate the existence of a long-run equilibrium relationship between the set of integrated variables using FMOLS and DOLS models. At the end, causality relationships between the variables are examined applying Dumitrescu and Hurlin (2012) method.

a. Panel co-integration tests

When it is established that all variables are non-stationary and integrated of same order, then panel co-integration relationship among variables is examined in the next step. The tests proposed by Pedroni (1999,2000,2004) allow for heterogeneity among individual members of a panel, including heterogeneity in both the long-run co-integrating vectors and in the dynamics, allowing for varying intercepts and slopes (Cheema and Javid, 2015). This test was initially designed to be applied in bi-variate context, indicating that this test has a higher power in comparison with other competing tests, especially in homogenous panels. Also, we would apply Westerlund (2005, 2006) test for panel co-integration, the underlying idea is to test for the absence of panel co-integration by determining whether there exists error correction for individual panel members or for the panel as a whole. Pedroni and Westerlund tests combine statistics computed for each individual in the panel, thereby producing a test with higher power. Furthermore, the limiting distribution of the combined test converges to a standard normal distribution after appropriate standardization, whereas tests for co-integration based on a single time series have nonstandard distributions. The tests share a common null hypothesis that y_{it} and x_{itare} not panel cointegrated by testing that $e_{(it)}$is non-stationary. Rejection of the null hypothesis implies that e_{it} is stationary and that the series y_{it} and x_{it} are panel cointegrated. The alternative hypothesis of the some panels in the Westerlund test is that the variables are co-integrated. The tests are based on the following panel-data model for I (1) dependent variable y_it as:

$$y_{it}=x_{it}'\beta_i+z_{it}'\gamma_i+e_{it} \quad (3)$$

where i = 1;…;N denotes the panel (individual) and t = 1;…;T denotes time. For each panel i, each of the covariates in x_it is an I (1) series. All the tests require that the covariates are not co-integrated among themselves. The Pedroni and Westerlund tests allow a maximum of seven covariates in x_it. βi denotes the cointegrating vector, which may vary across panels. γi is a vector of coefficients on zit, the deterministic terms that control for panel-specific effects and linear time trends. eit is the error term. Pedroni tests assume cross-sectional independence, but Westerlund test assumes cross-sectional dependence.

b. Panel FMOLS and DOLS estimates

When the variables are panel co-integrated, in the next step, we estimate the long-run equilibrium relationship among the variables with both panel Fully Modified Ordinarily Least Squares (FMOLS), and Dynamic Ordinary Least Squares (DOLS) methods is developed by Pedroni (2001) and also are proposed by Kao and Chiang (2000). When OLS estimator is applied to co-integrated panels it will be biased and inconsistent. For this reason, Pedroni suggested a fully modified OLS estimator, the FMOLS which becomes a dynamic OLS (DOLS). These estimators allow for a larger flexibility in the presence of heterogeneity in the examined co-integrated vectors (Pedroni, 1999, 2001, 2004). Furthermore, the above methods allow on the null hypothesis to test if there is a strong relationship between the model variable for the examined countries. The null hypothesis is H_0: β_i=β_0 for all i against the alternative H_1: β_i≠β_0, so that the values for β_iare not constrained to be the same under the alternative hypothesis. Examining the limited distribution of the FMOLS and DOLS estimators in co-integrated regressions, Kao and Chiang(2000) show that they are asymptotically normal. The FMOLS estimator is constructed by making corrections for endogeneity and serial correlation to the OLS estimator and is defined as:

$$\hat{\beta}_{FM} = \left[\sum_{i=1}^{N}\sum_{t=1}^{T}(x_{it} - \bar{x}_i)(x_{it} - \bar{x}_i)'\right]^{-1} \left[\sum_{i=1}^{N}\left(\sum_{t=1}^{T}(x_{it} - \bar{x}_i)\,\hat{y}_{it}^{*} + T\hat{\Delta}_{EM}^{*}\right)\right] \quad (4)$$

$\hat{y}_{it}$*is the transformed variable of y_{it} to achieve the endogeneity correction, where ($\hat{y}_{it}^* = y_{it} - \Omega_{EM}\ \Omega_{\epsilon}^{-1}\ \Delta x_{it}$), And $\hat{\Delta}_{EM}^*$ is the serial correlation correction term, where ($\hat{\Delta}_{EM}^* = \hat{\Delta}_{EM} - \hat{\Delta}_{E}\ \hat{\Omega}_{\epsilon}^{-1}\ \hat{\Omega}_{EM}$).

The serial correlation and the endogeneity can also be corrected using DOLS estimator. The DOLS is an extension of Stock and Watson (1993)'s estimator (Masih and Masih , 1996).

c. Panel Granger causality

The last step is to test for panel Granger causality relationships between the model variables proposed by Dumitrescu and Hurlin, 2012 (Lopez and Weber, 2017). Dumitrescu and Hurlin provide an extended test designed to detect causality in panel data. The significant advantage of this test is that it takes into consideration the dependence among the countries and heterogeneity. Moreover it can be performed when the time dimension (T) is higher or lower than the cross section dimension (N) as well. As in Granger (1969), the idea to determine the existence of causality is to test for significant effect of past values of x on the present value of y. It is possible to observe bidirectional causality (also called feedback). The test assumes there can be causality for some individuals but not necessarily for all.

5. Empirical results & discussions

5.1. Panel Unit root test results

This section provides stationary tests for the research model variables. According to the recent literature, there are various methods for unit root tests in panel data. To perform unit root tests, this paper applies the most common methods used in practice in the literature that include: Levin, Lin and Chu (LLC), 2002 Im, Pesaran and Shin (IPS), 2003 W-test; Breitung, 2000 t-stat; and ADF-Fisher, 1999 Chi-square tests. These four tests are applied in this study for improving reliability and validity of the results. The LLC panel unit root test assumes homogeneity in the dynamics of the autoregressive coefficients for all panel units. IPS test uses separate unit root tests for all cross-section units and average the ADF tests. Breitung finds that the power of LLC and IPS tests are decreased a lot with individual specific trends. Then Breitung suggests a test statistic without adopting a bias adjustment; based on results of MonteCarlo experiments, the test has higher power than LLC or the IPS (Baltagi, 2005). ADF-Fisher test was proposed by Maddala and Wu (1999), and it covers shortage of LLC and IPS tests. In all unit root tests, the null hypothesis is that the variable has a unit root (i.e., it is non-stationary) with the alternative hypothesis claiming that the variable does not have a unit root. It should be mentioned that all tests discussed here assuming independence of cross-sectional. The results of level and first difference unit root tests for the model variables except oil price are presented in Table 2.

As shown in Table 2, for both OPEC and non-OPEC panels, we fail to reject the null hypothesis of unit root for three series in the level of variables. But, the null hypothesis is rejected in the first differences for all three variables in OPEC and Non-OPEC panels at the 5% level of significance. This means that all the series are non-stationary in the levels but they are stationary in the first differences. Therefore, it reveals that all three variables in both panels are integrated of order one, I (1).

As you can see in Figures 1 and 2, the series of real oil price (ROP) have some break points. To find structural break points for series of real oil price, we perform Bai & Perron (1998, 2003) tests; and as real oil prices are the same for both OPEC and non-OPEC panels then we use Augmented Dickey Fuller (ADF), 1979 and Phillips and Perron (PP), 1988 unit root tests to examine stationary of real oil price. The results of Bai & Perron test shows that there is a break point in 2005, therefore we test for stationary on the whole sample period and individual segments in two sub-periods, 1990-2004 and 2005-2014. Table 3 shows the results of ADF and PP unit root tests for the ROP data series in the whole period and two sub-periods.

As indicated in Table 3, the ADF and PP test results show that real oil price is non-stationary in the variable level, but it is stationary in the first differences at the 1% level of significance; however, testing unit root without the possibility of a structural break yields an acceptance of the unit root hypothesis in most cases (Bai and Perron, 2003). Also, the both ADF and PP results show that real oil price is non-stationary in the levels over the first sub-period (1990-2004), but it is stationary in the first difference at the 5% level of significance. For the second sub-period (2005-2014), the levels of oil price is stationary at the 10% significance level, but it becomes stationary in the first difference at the 1% level of significance

Overall, the results of Tables 2 and 3 provide enough information to make it worthwhile to check for panel co-integration.

Table 2- The results of panel unit root tests of IVA, REC and CO2 for OPEC and Non-OPEC

OPEC						
Methods	IVA		REC		CO_2	
	Level	First Difference	Level	First Difference	Level	First Difference
Levin, Lin and Chu(LLC)	0.03	-2.37***	-0.43	-6.7***	-1.49*	-9.2***
Im, Pesaran and Shin(IPS)	-0.58	-7.38***	-0.77	-7.2***	-1..48*	-7.9***
Breitung	0.28	-2.65***	-1.03	-5.5***	0.23	-7.94***
ADF-Fisher	-1.18	31.8***	-2.16**	28.6***	-1.1	38.4***
Non-OPEC						
Methods	IVA		REC		CO_2	
	Level	First Difference	Level	First Difference	Level	First Difference
Levin, Lin and Chu(LLC)	-0.37	-4.86***	1.75	-6.54***	2.28	-10.38***
Im, Pesaran and Shin(IPS)	-1.05	-5.32***	1.49	7.15***	2.21	-6.82***
Breitung	-0.02	-4.4***	2.22	-6.32***	2.15	-4.86***
ADF-Fisher	-0.83	-16.1***	-0.68	33.4***	-1.46*	30.6***

Note: All variables are expressed in natural logarithms. Panel unit root tests are without trend. ***,**,* denote rejection of the null hypothesis at the 1%, 5%, 10% level of significance, respectively. The optimal lag length is selected using Akaike Information Criteria (AIC). Source: Authors' findings

5.2. Panel Co-integration tests results

Given that each variable is integrated of order one, next step is to test for panel co-integration. We apply two types of panel cointegration tests in this paper. The first test is suggested by Pedroni (1999, 2004) who provides three panel cointegration statistics for testing the null hypothesis of no co-integration in heterogeneous panels. These tests include Modified Phillips-Perron t statistic, Phillips-Perron (PP) t-statistic, and Augmented Dickey-Fuller (ADF) t-statistic. All of these tests are conducted based on the estimated residuals from Eq. (2). Based on Pedroni's tests results presented in Table 4, PP t-statistic and ADF t-statistic indicate strong evidence of co-integration in OPEC and non-OPEC panels; modified PP t-statistic shows no panel co-integration evidence for both panels even at the 10% significance level. The results of panel co-integration tests are mixed. The results of Pedroni's tests in Table 4 indicate at least some evidence of panel co-integration among renewable energy consumption, industrial productions, CO2 emissions and oil prices for both panels. Therefore, according to Pedroni's panel co-integration tests, the model variables have a long-run relationship.

The second panel cointegration test based on the estimated residuals is developed by Westerlund (2005, 2006). The Westerlund test uses yet another approach, one that imposes fewer restrictions. It tests the same null hypothesis, but the alternative hypothesis is different, namely that some (not necessarily all) of the panels are cointegrated. The panel co-integration test of Westerlund among the variables indicates the presence of panel co-integration at 5% significance level for non-OPEC; but, in case of OPEC the null hypothesis is not rejected even at the 10% significance level.

According to the results of the Pedroni and Westerlund co-integration tests in Table 4, it is verified that there is a cointegrated relationship among the renewable energy consumption, industrial value added, CO2 emissions and real oil prices at the 5% significance level for both non-OPEC and OPEC panels. In the other words, there is a long-run equilibrium relationship among the model variables for both panels, showing that all variables are moving together in the long-run. Hence, the directions of causality between the research model variables are examined below.

5.3. Panel Granger causality test results

For analyzing the potential direction of the causal relationship among the variables, this paper uses the heterogeneous panel Granger causality test developed by Dumitrescu and Hurlin (2012), which can return successful results even under the conditions of cross-sectional dependence. The results of panel Granger causality test is presented in Table 5 for both panels of

Table 3- The results of Unit root tests for real oil price (ROP)

Unit Root Test	Augmented Dickey-Fuller(ADF)		Phillips&Perron(PP)	
	Level	First Difference	Level	First Difference
ROP (1990-2014)	-2.87	-4.63***	-2.88	-4.67***
ROP (1990-2004)	-1.836	-3.134**	-1.836	-3.106**
ROP (2005-2014)	-2.678*	-3.212***	-2.960**	-3.283***

Note: The variable ROP is in natural logarithms. ***,**,* denote rejection of the null hypothesis at the 1%,5%, 10% level of significance, respectively. The test regressions contain individual intercept and time trend. The optimal lag length is selected using Akaike Information Criteria (AIC).

Table 4- The results of Panel co-integration tests for OPEC and Non-OPEC

Panel Co-integration Test		OPEC		Non-OPEC	
	Models Including	Panel statistics	P-value	Panel statistics	probability
Pedroni (1999,2004)	Modified PP t	-0.15	0.43	-0.94	0.17
	PP **t**	-4.37***	0.000	-6.05***	0.000
	ADF t	-3.04***	0.001	-6.84***	0.000
Westerlund (2005,2006)	Variance ratio	-0.95	0.16	-1.79**	0.03

Note: The null hypothesis is that the variables are not panel co-integrated. The tests assume individual intercept but no deterministic trend. ***,**,* denote rejection of the null hypothesis at the 1%, 5%, 10% level of significance, respectively. Automatic lag length is selected using Schwarz Information Criteria (SIC). Source: Authors' findings

OPEC and non-OPEC.

According to the test results in Table 5, a unidirectional causal relationship is found from industrial value added per capita to renewable energy consumption per capita between the years of 1990 and 2014 in non-OPEC countries, showing that renewable energy is not cause of industrial value added in non-OPEC countries; but, there is a relationship of bidirectional causality between industrial value added and renewable energy consumption in OPEC countries. According to this, renewable energy consumption supports industrial productions in OPEC and non-OPEC countries. Renewable energy consumption encourages industrial productions and, for the same purpose, industrial productions encourage renewable energy consumption in two groups of countries. Also, a relationship of unidirectional causality is found from CO_2 emissions per capita to renewable energy consumption per capita for both OPEC and non-OPEC over the study period; it means that renewable energy consumption is not cause of CO_2 emissions in two panels. However, given the long-run causality results, a bi-directional causal relationship is found between the rest of research variables in OPEC and non-OPEC countries over 1990 -2014 period. This means that there is bidirectional causality between IVA and CO_2, IVA and ROP, CO_2 and ROP, and REC and ROP in both panels over the sample period. Therefore, considering Dumitrescu and Hurlin panel causality test results, we would conclude the following remarks in both OPEC and non-OPEC countries: Industrial value added Granger causes CO_2 emissions and vice versa, Industrial value added affects real oil prices and vice versa; CO_2 emissions Granger causes real oil prices and vice versa, and Finally renewable energy consumption impacts real oil prices and the opposite is true as well.

These results support the feedback hypothesis between the research variables for both OPEC and non-OPEC panels during 1990-2014. The next step is to estimate coefficients of long-run relationship among the model variables. The results are given below.

5.4. Panel FMOLS & DOLS estimates

As the existence of the panel cointegrating relationship is supported, we estimate a long-run renewable energy consumption function given by Eq. (2) using the FMOLS and FMOLS estimators. FMOLS and DOLS estimates of Eq. (2) are reported in Table 6. The FMOLS and DOLS are based on group-mean estimates. According to the FMOLS and DOLS results, in OPEC and non-OPEC countries, the estimated coeffcients of industrial productions and real oil prices are positive and statistically significant at the 1% level of significance (except the coefficient of industrial

Table 5- Heterogeneous Dumitrescu-Hurlin panel causality test results for OPEC and Non-OPEC

OPEC		Non-OPEC	
Direction of causality	Yes or No	Granger causality	Yes or No
REC causes IVA	Yes	REC causes IVA	No
IVA causes REC	Yes	IVA causes REC	Yes
IVA causes CO2	Yes	IVA causes CO2	Yes
CO2 causes IVA	Yes	CO2 causes IVA	Yes
REC causes CO2	No	REC causes CO2	No
CO2 causes REC	Yes	CO2 causes REC	Yes
IVA causes ROP	Yes	IVA causes ROP	Yes
ROP causes IVA	Yes	ROP causes IVA	Yes
CO2 causes ROP	Yes	CO2 causes ROP	Yes
ROP causes CO2	Yes	ROP causes CO2	Yes
ROP causes REC	Yes	ROP causes REC	Yes
REC causes ROP	Yes	REC causes ROP	Yes

Source: Authors' findings

productions in OPEC and real oil prices' coefficients in non-OPEC of DOLS estimates are not significant). But, the estimated coefficients of CO_2 emissions are negative and statistically significant at the 1% significance level for both OPEC and non-OPEC using FMOLS and DOLS estimators. These findings show that industrial productions and real oil prices have positive and CO_2 emissions has negative and significant impact on renewable energy consumption of OPEC countries in long-run over 1990 -2014 period. Also, findings for non-OPEC countries show that industrial productions and CO_2 emissions have significantly positive and negative impact, respectively on renewable energy consumption of these countries during the examined period. The parameter estimates of FMOLS and DOLS models can be interpreted as long run elasticities. For each variable, the panel estimated elasticity is remarkably similar in sign and magnitude across the two estimation methods.

According to the estimated coefficients for FMOLS method in Table 6, on average, if other things being equal, a 1% increase in industrial value added, increases renewable energy consumption for OPEC and non-OPEC by 0.23% and 0.63%, respectively. That means that changing industrial value added has a greater effect on renewable energy consumption in non- OPEC countries than OPEC countries. Also, 1% increase in CO_2 emissions affects negatively on renewable energy consumption of OPEC and non-OPEC nations by 1.65 %, and 1.47%, respectively. It means that considering negative effect of CO_2 emissions on renewable energy consumption, changing CO_2 emissions has bigger effect on renewable energy consumption in OPEC countries in comparison to non-OPEC (but DOLS coefficients are smaller showing an opposite results). In addition, 1% rise in real oil price has positive effect on renewable energy by 0.3% and 0.24% for FMOLS and DOLS estimators, respectively in OPEC, but it doesn't have meaningful effect on renewable energy in non-OPEC countries. This shows that non-OPEC countries have already devised to substitute renewable energies for fossil fuels in their industrial sector since 1970's that changing oil price does not have meaningful impact on renewable energy consumption in industrial sector over the study period. The conclusion is that because of key role of renewable energies in non-OPEC countries, the industrial sector value added has greater impacts on renewable energy consumption than OPEC, and for the same reason, increasing CO_2 emissions affect inversely renewables in non-OPEC by greater extent than OPEC. Furthermore, depending on fossil fuels, oil prices leave a positive and meaningful effect on renewable energy consumption in OPEC countries, but real oil prices do not seem to have a significant and strong impact on renewable energy consumption in non-OPEC countries. Considering economic theory, in term of the relationship among the research variables in Tables 5, the FMLOS and DOLS results indicate a long-run equilibrium relationship among renewable energy consumption, industrial value added, CO_2 emissions and real oil prices for both selected OPEC and non-OPEC panels.

Policy makers need to be aware of the fact that in the long term, panel estimated industrial productions and CO_2 elasticities are both statistically significant highlighting the importance of these two variables that play in helping to explain renewable energy consumption in two OPEC and Non-OPEC countries. Also, the large long term panel estimated industrial productions elasticities of renewable energy consumption are consistent with the view that in higher industrial value added, managers in industrial sector are more likely to be concerned with environmental issues and can invest in renewable energies. Non-OPEC countries are also more likely to have access to or the development of new technologies that are important in production increase and use of renewable energy.

6. Conclusion & policy recommendations

Increased economic and societal concern over issues related to energy security and global warming suggests that in the future there will be a greater reliance on the consumption of renewable energy. This paper presents and estimates an empirical model of renewable energy consumption for industrial sector of selected OPEC and non-OPEC countries during 1990 to 2014. Panel cointegration tests developed by Pedroni (1999,2004) and Westerlund (2005,2006) indicate that there is a long-run equilibrium relationship among renewable energy consumption, industrial value added, CO_2 emissions and real oil price in two panels of OPEC and non-OPEC countries over the sample period. These results are robust across two different panel co-integration methods. The results of panel Granger causality using Dumitrescu and Hurlin (2012) shows that there are bi-directional causality relationships between research variables confirming feedback hypothesis. In the long term, FMOLS and DOLS estimators confirm that increases in industrial value added per capita and CO_2 emissions per capita are found to be major drivers behind per capita renewable energy consumption; oil prices have a lesser but positive impact on renewable energy consumption in non-OPEC panel than OPEC. Finally, Long term elasticities estimated from a panel co-integrated FMOLS and DOLS models show that a 1% increase in industrial value added per person increases per capita renewable energy consumption by a greater magnitude in non-OPEC than OPEC; also a 1% increase in CO_2 emissions per person increases per capita renewable energy consumption by a greater degree in non-OPEC in comparison to OPEC nations. According to these findings it is clear that renewable energy consumption in non-OPEC countries is affected by industrial productions and CO_2 emissions more than OPEC countries.

Over the Earth's history, the climate has changed for many reasons including human activities that release emissions of gases and other pollutants into the atmosphere known as greenhouse gases (GHG). The impact of GHG includes increased air and ocean temperatures, drought, melting ice and snow, rising sea levels, changes in rainfall patterns and flooding. The main greenhouse gases are carbon dioxide (CO_2) emissions that are primarily released through consuming and burning fossil fuels. To maintain a sustained growth of countries, renewable energies should be replaced with fossil fuels in various economic sectors. Therefore, policy makers in energy sector should understand important role of renewable energies for climate protection and invest in renewable energies, and also convey concerns about climate change to public. On the other hand, policy makers need to be aware of the fact that in the long term, panel estimated industrial productions and oil prices elasticities of renewable energy consumption are both positive and statistically significant highlighting key role of these variables in explaining renewable energy consumption. Therefore, in case of non-OPEC and especially OPEC countries, the industrial sector is mainly dependent on fossil fuels use, and there are concerns that the drop in price of fossil fuels can postpone investments in renewable energies due to the higher cost of renewable energies. Given this situation, there are opportunities for policy makers in these countries to decrease subsidies on fossil fuel consumption Hence, these countries need to prepare their industrial sectors not to be vulnerable against shocks in fossil fuel prices. Also, the governments in OPEC and non-OPEC countries should financially support technological innovations to decrease the cost of consuming renewable energies in industrial sector and other sectors of their economies; therefore, renewable energies could compete with fossil fuels in production system in industrial sector and other sectors and sub-sectors.

Table 6- The results of FMOLS & DOLS estimates for OPEC and Non-OPE (LREC as dependent variable)

	LIVA		LCO2		LROP	
Panel	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS
OPEC	0.23***	0.02	-1.65***	-0.59***	0.30***	0.24***
Non-OPEC	0.63***	0.58***	-1.47***	-1.22***	0.005	0.02

Note: Method: Fully-modified OLS (FMOLS) and Dynamic OLS (DOLS). Panel method: Grouped estimation. Cointegrating regression does not contains constant and trend. ***and ** Indicate statistical significance at the 1% and 5% levels, respectively. All variables are estimated in natural logarithms. Source: Authors' findings

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