

Does Higher Oil Prices Influence Renewable Energy Consumption? A Cross-sectional Approach

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Abstracts: One of the most effective strategies to mitigate global warming is to reduce the use of fossil fuels in the generation of energy. Thus, transitioning to renewable energy is critical to long-term sustainable growth. One of the Sustainable Development Goals of United Nations is to transition towards renewable energy. But many resource-rich economies are faced with numerous barriers towards the transformation process. In this regard, we examine the effect of increased oil prices, income, information communication technology, and financial development on renewable energy consumption in some OPEC member nations from 1980 to 2020. The findings shows that oil price has a negative effect on renewable energy consumption. While information communication technology moderates the relationship between financial development and renewable energy consumption. Therefore, A green finance system helps a country to build an ecologically sound renewable energy system, which greatly stimulates the usage of renewable energy. Green financial institutions should be formed in all sample nations to encourage financial activity and support environmentally beneficial projects.

Keywords: Renewable energy transition, DCCE, Oil prices, Income, ICT.

1. INTRODUCTION

In the contemporary world, energy is absolutely essential to achieving the necessary rate of economic expansion. This is so because energy is a crucial component of every sector of an economy, which means that without it, it would be impossible to produce goods and services. At the current situation, when a nation's economy grows, so does its need for energy (Sadorsky, 2009). However, using conventional means of energy (fossil fuels) to generate energy, causes environmental degradation since it releases carbon dioxide (CO₂) into the atmosphere, which raises the world temperature Stern (2006). As such, although while greenhouse gases (carbon dioxide, methane and nitrous oxide) are seen as product of economic activity that promote economic expansion and wealth, they are also seen as one of the main causes of environmental deterioration (Svetlana et al., 2012). Rising potential negative repercussions of global warming as caused by of unrestrained use of fossil fuels continue to be an unsolved worldwide challenge. Based on Nordhaus (1975), an increase in global temperature could cause inescapable and irreversible problems for Earth's inhabitants. At the same time, the Intergovernmental Panel on Climate Change predicts that global warming would hit 1.5 degrees Celsius between 2030 and 2052 if present trends continu (IPCC, 2017). Such predictions and awareness pique the interest of academics, and as a result, studies that aim to provide solutions for limiting human-caused global warming and reducing its potentially negative consequences are increasing significance and popularity.

One of the most effective strategies to reduce global warming is to eliminate the use of fossil fuels in the generation of energy. Renewable energy is one of the most essential alternatives to fossil fuels. Absolutely no carbon dioxide is emitted into the environment throughout the process of gathering energy from renewable sources like wind and sunlight (Liu et al., 2021). However, in comparison to fossil fuels, the process of installing renewable energy sources is extremely expensive. Additionally, this condition makes investors more anxious about renewable energy initiatives (Zhe et al., 2021). Thus, nations must take steps to enhance their financial commitments in renewable energy (Li et al., 2020). On the contrary, the growth of financial systems in countries makes it easier for renewable energy producers to obtain the needed resources (Armeanu et al., 2021). This will be beneficial to the expansion of these initiatives.

Similarly, ICT supports efficient, high-quality communication by lowering communication costs, and its use has risen globally in recent decades. ICT is so pervasive in today's growing digital organizations, influencing every element of human existence. Because of the tremendous impact of technological advances on socio-economic processes, ICT dissemination is frequently seen as an important component in the growth of the economy and society. ICT is driving the expansion of financial technological innovation and data analytics by institutions of finance, both of which are critical components of the financial inclusion approach. In addition, ICT contributes to the rapid spread of financial advances throughout the world, resulting in significant shifts in the global economic environment. The electronic financial system created by the constant growth and convergence of finance and digital technologies makes a broad spectrum of financial goods or services accessible to formerly unbanked populations. Linking ICT with the finance industry increases growth in the economy and minimizes income inequality through financial development.

In order to safeguard the environment while lowering the emission of greenhouse gases, several advanced and developing nations signed the Kyoto Protocol in 1997. The purpose was to reduce the release of greenhouse gases. In the beginning, developed-country emission reduction objectives were established. However, it was later discovered that emerging countries' contribution of emissions greatly outperformed that of advanced nations (Winkler, Spalding-Fecher and Tyani, 2002). Amongst developing economies, rich in resources, oil-producing, and export-oriented nations account for a sizable share of emissions (Hasano et al., 2019). These countries have an abundance of natural assets (oil, gas, etc), and using these traditional sources to produce energy is more affordable than using other forms of energy. In this sense, to get energy, many countries rely on cheap natural assets, which may result in significant greenhouse carbon emissions. Given this, analyzing the association between oil prices as well as the transition to clean energy sources for these oil-producing countries takes on added significance.

In this perspective, it is critical to investigate the relationship between oil prices, FD, income, ICT, and renewable energy transitioning in some OPEC member nations. The Organization of Petroleum Exporting Countries (OPEC) is one of the world's largest oil cartels, having seven African countries among its 13 members as of the fourth quarter of 2020. Algeria, Angola, Congo, Equatorial Guinea, Gabon, the Islamic Republic of Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, the United Arab Emirates, and Venezuela formed the member nations. OPEC member nations accounted for approximately 79.11% of the total 1,551 billion barrels (bn b) of globally proved oil reserves and approximately 35.47% of the total projected 206.2 trillion standard cubic meters (tr s cu m) of globally confirmed natural gas reserves (OPEC 2020). A large number of OPEC member nations continue to be economically dependent on fossil fuels. In these nations, crude oil energy has mostly continued to be the main engine of the economy via revenues in foreign exchange along with the main source of energy for rising energy demand.

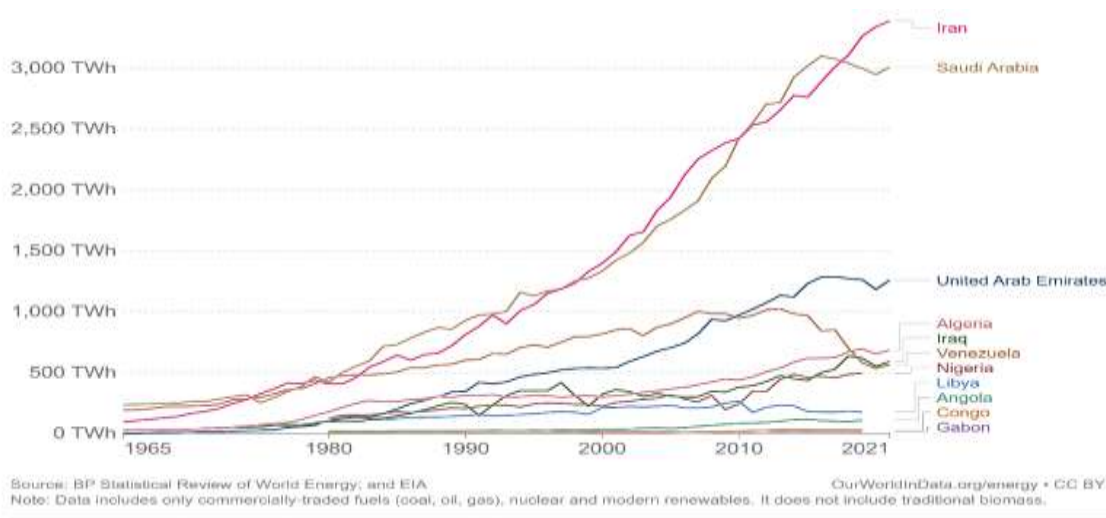


Figure 1. Total Energy Consumption

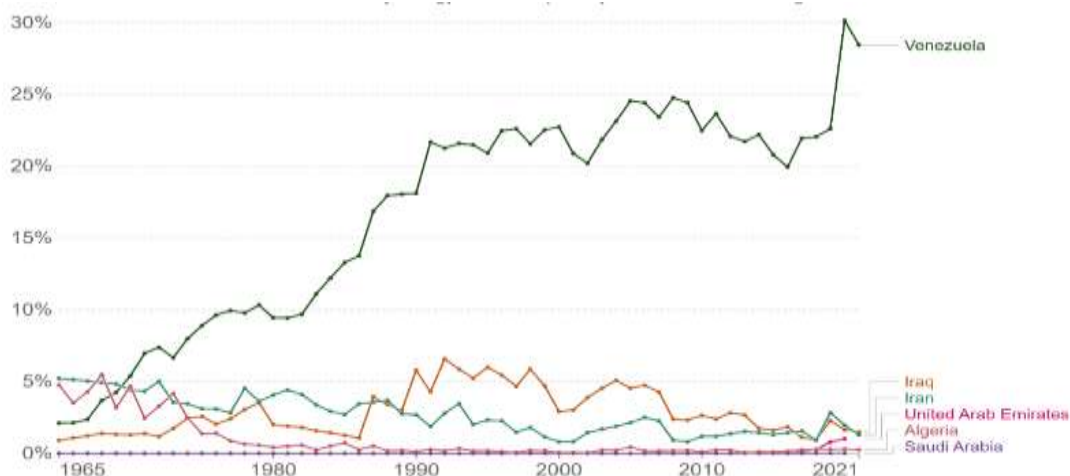


Figure 2. Total Renewable Energy Consumption

The overall amount of main energy usage in these countries (figure 1) was almost completely created out of natural gas and oil. Despite a large potential for renewable energy, Fig. 2 shows that the amount of renewables in these nations has decreased over time. Although, some economies have begun to give renewable energy political consideration by setting up aggressive renewable goals. Growing power demand, dwindling fuel subsidies, plus a need for significantly improved energy security are pushing the rightful authorities' pursuit of renewable energy.

Although natural gas and petroleum products cover over 95 percent of the majority of these nations' total energy demand, other forms of energy like hydropower, nuclear, as well as others meet less than 5% of total energy demand (Wheeler and Desai, 2019). In terms of carbon emissions during the last couple of decades, almost every one of these countries, including Iran, Nigeria, and others, emit less than Japan and Germany. However, from economic perspective, these nations have a lower GDP. They are transitioning towards renewable energies in a bid to mitigate CO₂ emissions. Yet, there are certain impediments to the clean energy transition. Most of these barriers include the availability of cheap options (natural gas and oil) that can easily replace clean energy sources, their desire for a large initial investment to build renewable energy centres, the banks' inability to provide long-term financing at cost-effective interest rates, alongside others (Ritchie and Roser, 2023). The findings give a solid foundation for combining ICT with financial development to foster renewable energy usage and accomplish a climate-friendly energy conversion. Our study adds to current knowledge on oil price, income, ICT, financial development, and renewable energy usage in these resource-rich countries, which are among the world's largest atmospheric carbon emitters. As a result, the goal of this research is to investigate the influence of rising oil prices on renewable energy use, as well as examine the integrating function of ICT in the relationship between financial development and the use of renewable energy for a few OPEC member nations. Our research questions seek to 1) investigate whether or not higher oil prices will cause oil-exporting nations to focus more on exploitation and exports, while ignoring the renewable energy industry and usage; and 2) investigate whether or not the integral role of ICT in the relationship between financial development and renewable energy use fosters environmentally friendly energy transition.

2. LITERATURE

2.1 Oil Price and Renewable Energy Consumption

Economic literature has seen a significant increase in energy-related study over the last decade, which is attributed to the rising concerns about the hazards posed by rising carbon emissions. Many variables have been linked to an increase in global GHG emissions, attracting multiple research efforts on potential techniques for decreasing global GHG emissions during a specified time span (Randers 2012). Researchers have long looked into how oil prices (OILP) affect the consumption of clean energy. In this context, we analyzed the study examining the

impact of oil prices on the usage of renewable energy for various economies. Sadorsky (2009b) used different panel cointegration methodologies to examine the impact of oil prices, GDP per capita, and CO₂ emissions on REC across G7 countries. Yearly data from 1980 until 2005 were used for the estimation. He discovered that whereas GDP per capita and CO₂ emissions have a positive and statistically significant effect on REC, oil prices exhibit an adverse effect. Marques and Fuinhas (2011) investigated the impact of the oil price on REC and found it to be empirically insignificant for 24 European Union nations using the GMM approach. Salim and Rafiq (2012) investigated the connection between REC, real GDP, and oil price for six rising nations using panel FMOLS, panel DOLS, and ARDL techniques. Based on the results of the ARDL, oil prices exert a negative and significant affect on REC throughout China and Indonesia, but not in Brazil, India, the Philippines, or Turkey. Moreover, the outcomes of the panel DOLS and FMOLS demonstrated that the impact of oil price is not statistically significant. Likewise, Payne (2012) established the absence of causation between actual oil prices and REC in the instance of the United States by applying the Toda-Yamamoto causality test over the time frame 1949-2009.

Tuzcu and Tuzku (2014) investigated the connection between REC, real oil prices, real GDP, CO₂ emissions, and proved oil reserves in 7 OPEC countries. They used panel data approaches to conduct empirical study on data spanning 1980 to 2006. The results indicated that the oil price exhibits no statistically significant influence on REC. Apergis and Payne (2014a) examined the influence of oil prices on REC for 25 OECD nations using data spanning 1980 to 2011. They discovered that an increase in actual oil prices causes an increase in REC over the course of time. Apergis and Payne (2014b) for seven Central American countries, Azad et al. (2014) for Australia, Apergis and Payne (2015) for eleven South American nations. Omri, Daly, and Nguyen (2015) showed positive effects of oil price on REC in 64 nations, while Padhan et al. (2020) found a positive effect of oil price on REC in the OECD nations. Furthermore, Chen et al. (2021) discovered that actual oil prices have a positive impact on REC in fewer democratic nations while having no effect in larger democratic nations.

Furthermore, the inflation rate is an important factor in growing renewable energy investments. In this perspective, high inflation rates cause market uncertainty. This predicament is causing investors to become increasingly concerned (Azam and Haseeb, 2021). The fundamental explanation is that investors fail to make sound investment decisions given that they're unable to effectively forecast the future (Jahangir and Cheraghi, 2020). Because of this issue, increasing renewable energy investments in nations with high inflation rates is extremely challenging (Selmi et al., 2020). As a result, for these initiatives to improve, nations' inflation rates must be reasonable (Adom et al., 2021). Mousavi et al. (2021) attempted to develop acceptable investment techniques to enhance investments in clean energy sources. They highlighted how the inflation rate has a significant impact on this goal. Deka et al. (2021) investigated the association between renewable energy investments and inflation rates. They came to an agreement that steady inflation was necessary for the enhancement of these investments. In their study, Chaurasia et al. (2021) also emphasized the importance of this circumstance.

Nguyen and Kakinaka (2019) evaluated the factors that determine REC for a number of nations defined by income levels and found a positive and statistically significant effect for low- and high-income nations, as well as a negligible negative influence for middle-income nations. Using GMM and Panel VAR techniques, Deniz (2019) discovered a positive impact from oil price to REC for oil-importing nations and a negative influence for oil exporting nations. According to a study of a similar line (Bamati and Roofi, 2020), the cost of oil has a beneficial effect on the usage of renewable energy in both emerging and developed countries. Mukhtarov et al. (2020), on the other hand, discovered a negative impact of oil prices on REC when applying Structural Time Series Modelling (STSM) to Azerbaijan data set ranging from 1992 to 2015. Likewise, Murshed and Tanha (2020) discovered a negative influence of oil price on REC in the cases of Bangladesh, India, Pakistan, and Sri Lanka. Mukhtarov et al. (2021), for Kazakhstan, and Karacan et al. (2021), for Russia.

2.2 Financial development and Renewable energy Consumption

Another important determinant for the advancement of renewable energy investment initiatives is financial development (Muyambiri and Odhiambo, 2018). The biggest downside of renewable energy investments is their high upfront price (Shahbaz et al., 2021). This scenario provides an important impediment to improving these

projects. As a result, cash should be made available to renewable energy investors in order to expand these kinds of initiatives (Kirikkaleli and Adebayo, 2021). Due to this problem, when a country experiences financial development, renewable energy investors would be more interested in entering that country because of the ease with which they can access funding (Usman and Makhdam, 2021). Lei et al. (2021) investigated the association between financial development and renewable energy investments for China. They argued that financial advancements have a good impact on the expansion of these ventures. Furthermore, Wang et al. (2020) concentrated on the relationship between carbon emissions, financial development, and renewable energy usage. They came to the same conclusions. Likewise, Khan et al. (2020) and Lahiani et al. (2021) discovered that financial development contributes significantly to the enhancement of renewable energy funding (Sulong and Farouq, 2023). Additionally, quite number of studies investigated these linkages, some of which are: Wu and Broadstock (2015) conducted for 22 developing nations, Khan et al. (2020) conducted for Russia, Kutan et al. (2017) conducted for BRICS, Khoshnevis Yazdi and Shakouri (2017) conducted for China, Alsaleh and AbdulRahim (2019) conducted for 28 European Union economies, Eren et al. (2019) conducted for India, Khan et al. (2020) conducted for 192 economies, Anton and Afloarei Nucu (2019) conducted for 28 European Union economies, Mukhtarov et al. (2020a) conducted for Azerbaijan, as well as Liu et al. (2020) conducted for BRICS nations. They have all found a positive effect of financial development in relation to renewable energy usage.

2.3 ICT and renewable energy consumption

Rapid ICT growth has an impact on energy usage in the age of digital economy. Even though numerous scholars are studying the relationship between ICT and energy usage there is no common ground regarding the influence of ICT on energy usage. Instead, a rise or drop in general ICT-related energy usage is determined by the income effect of economic vitalization as well as the replacement effect of an overhaul in the industrial framework. According to several researchers, ICT increases energy efficiency while decreasing energy usage. According to Li and Du (2021), for every 1% improvement in the internet advancement index, an organization's energy efficiency rises by around 0.38%. According to Wu et al. (2021), internet growth directly enhances local green overall energy performance. Usman et al. (2021) illustrates an increase in energy effectiveness in India as a result of greater ICT use. According to Moyer and Hughes (2012), the proliferation of internet-based technologies promotes efficiency and lowers energy use. Similarly, Amri et al. (2019) discover that ICT enhances energy efficiency and saves energy. According to Ishida (2015), ICT investment results in a slight reduction in energy use. According to Zhou et al. (2018), ICT input replacement improves lower energy consumption in production. Other research, however, indicates that ICT usage could boost energy use. According to Sadorsky (2012), there is a considerable positive association between ICT usage and electrical usage in developing nations. Salahuddin and Alam (2016)⁶⁵ confirm that ICT use increases electrical consumption in both the short and long term. According to Lange et al. (2020), technological advancement enhances energy consumption, and this has a bigger energy-increasing impact compared to an energy-saving benefit. According to Magazzino et al. (2021), ICT application is a significant driver of electrical consumption. According to Kouton (2019), ICT growth has a positive impact on energy demand since the energy efficiency gains of ICT growth have not yet been realized in the research nations.

According to the literature assessment, no study has looked into the influence of rising oil prices and financial development on renewable energy consumption in these 11 OPEC nations. Also, no study has looked into the role of ICT in the relationship between financial development and REC in these OPEC member countries. As a result, the current study aims to bridge this gap by investigating the long-run relationship between these variables using the DCCE approach, which gives more accurate results using heterogeneous econometrics techniques. The research's conclusions may be helpful for the economic policymakers of these nations to have a knowledge of the present climate and develop suitable strategies that promote environmentally friendly energy consumption. It may also add to the empirical literature to feed future investigations in the light of developing oil-exporting nations.

3. METHODOLOGY

3.1 Model specification and data

The following studies presented a model through which energy consumption is estimated as a function of financial development, economic growth, and oil price. Ali et al. (2015), Chang (2015), Mukhtarov et al. (2018), and Mukhtarov et al. (2020b). Following an analogous theoretical structure, Mukhtarov et al. (2020a) have established a model through which renewable energy use is a function of financial development, real GDP per capita, and the consumer price index as an indicator for energy prices. Nevertheless, for the purpose of analysis, the present research included theory-related variables (Castle et al., 2021). In the context of empirical estimations, the subsequent functional model is used:

$$rec_{it} = f(oip, fd, inc, ict) \quad (1)$$

Where *rec* is the renewable energy consumption per capita, *inc* is the per capita GDP, *oip* is the oil price and *ict* is the information communication technology. The applied indicators for these determinants are well explained in the Data section. For the empirical analysis we used the DCCE model which is expressed

$$\ln REC_{it} = \beta_0 + \beta_1 \ln OILP_{it} + \beta_2 \ln FD_{it} + \beta_3 \ln INC_{it} + \beta_4 \ln ICT_{it} + \varepsilon_{it} \quad (2)$$

Where *REC* is renewable energy consumption, *INC* is Gross Domestic Product per capita, and *FD* is financial development, *OILP* is consumer price index as a proxy of oil prices, *ICT* is the information communication technology while ε is the error term.

The study hypothesizes that *ICT* moderates the linkage between financial development and renewable energy consumption. As a result, the model presented in equation 2 is expanded to include the interaction term ($\ln ICT * \ln FD$) to measure the indirect effect of financial development on renewable energy through the route of *ICT*.

$$\ln REC_{it} = \beta_0 + \beta_1 \ln OILP_{it} + \beta_2 \ln FD_{it} + \beta_3 \ln INC_{it} + \beta_4 \ln ICT_{it} + \beta_5 (\ln ICT * \ln FD)_{it} + \varepsilon_{it} \quad (3)$$

Equation (2,3) can be analyzed with the parameters' log form. The study conducts this research using annual data for 11 selected OPEC member countries from 1980 to 2020. Our explained variable is *rec*, which denotes renewable energy consumption (Sulong and Farouq, 2021). The oil price (*OILP*) is estimated through the consumer price index (Farouq and Sulong, 2020). Income is measured through GDP per capita. Mobile subscriptions (per 100 people) are used to measure *ICT*. Meanwhile, *FD* is measured by domestic credit to private sector (Farouq et al., 2021; 2020). The data of *REC* is obtained from Our World in Data (Our World in Data, 2023). The data of *OILP*, *GDP*, *ICT*, *INC* and *FD* are all generated from World Bank Group database (World Bank, 2023). In the estimation analysis, all parameters are analyzed in logarithm form.

3.2 Estimation strategy

3.2.1 Cross-sectional dependency test

Cross-sectional dependence is the most identified issue in panel sequence analysis. The CD problem could arise as a result of unobserved shocks that bias the results. To solve this issue, we apply Pesaran's (2004) approach. The testing equation is as follows:

$$CD = \sqrt{\frac{2T}{N(N-1) \left[\sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\delta}_{ij} \right]}} \quad (4)$$

Where $\hat{\delta}_{ij}$ shows the pair-wise correlation residual estimate sample, while *T* & *N* are for cross-sections and period.

3.2.2 Slope homogeneity tests

After examining the cross-sectional connection, it is necessary to examine the slope homogeneity because there can be variances between nations in terms of demography, finance, and socioeconomic structure. To attain this goal, the Pesaran and Yamagata (2008) slope homogeneity test is used. The test mathematical equations are outlined below:

$$\Delta_{Sh} = (N) \frac{1}{2} (2f) \frac{1}{2} \left[\frac{1}{N} S - f \right] \quad (5)$$

$$\Delta_{ASh} = (N) \frac{1}{2} \left(\frac{2f(T-f-1)}{T+1} \right) \frac{1}{2} \left[\frac{1}{N} S - f \right] \quad (6)$$

Δ_{Sh} and Δ_{ASh} denotes the delta tilde and adjusted delta tilde, respectively.

3.2.3 Unit Root Test

To assess the combined properties of variables while validating the CD and heterogeneity in slope coefficients, second-generation unit root analyses are required. In this context, Pesaran's (2007) cross-sectional augmented Dickey-Fuller (CADF) and I'm Pesaran-Shin (CIPS) unit tests are used. These unit root tests perform better than the first-generation unit root test in terms of efficiency and reliability and are best used with heterogeneous panel data.

3.2.4 Cointegration Test

Following the diagnostic of stationarity, the long-run cointegration link of the underlying variables is determined. In this study, the ECM panel cointegration test developed by Westerlund (2007) is applied. This test offers efficient results in the context of slope heterogeneity and cross-sectional dependence. As such, the cointegration approach established by Westerlund (2007) is employed in this study to investigate the links between financial development, oil price, ICT, income, and renewable energy consumption in the 11 OPEC member states. This test, based on Kapetanios et al. (2011), is more reliable and consistent when the error elements are cross-sectionally dependent. The following equations are provided:

$$\delta_i(L)\Delta y_{it} = \gamma_{2it} + \beta_i(y_{it} - 1 - \delta_i x_{it}) + \kappa_i(L)V_{it} + \varphi_i \quad (7)$$

The test statistics of this technique are given below:

$$G_t = \frac{1}{N} \sum_{i=1}^N \frac{\delta_i}{SE(\delta_i)} \quad (8)$$

$$G_\delta = \frac{1}{N} \sum_{i=1}^N \frac{Y\delta_i}{\delta_i(1)} \quad (9)$$

$$P_r = \frac{\delta}{SE(\delta)} \quad (10)$$

$$P_\delta = Y\delta \quad (11)$$

where Eqs. 8 and 9 shows the group means statistics, involving G_a and G_t . While equations 10 and 11 denote the panel statistics involving P_a and P_t . The technique has both null and alternate hypotheses of “no cointegration” as well as “cointegration,” accordingly.

3.2.5 Estimation

Economists proposed various econometric approaches for empirical assessment of panel data. However, first-generation relationship estimating techniques, such as Fully modified ordinary least squares (FMOLS), may generate biased results due to the presence of cross-sectional dependency and heterogeneity in panel data. Chudik and Pesaran's (2015) Dynamic Common Correlated Effect (DCCE) estimator is resilient to non-stationarity and endogeneity difficulties, in addition to cross-sectional dependence and heterogeneity problems. Therefore, the DCCE technique is utilised to assess the connections between the variables. Blackburne and Frank (2007) supplied the `xtpmg` command, which is used to estimate the pooled mean group in the situation of non-stationary and heterogenous large datasets. However, because the PMG does not account for cross-sectional dependency, Eberhardt (2012) used a common correlated effect with no pooled coefficients. The CCE technique, like the DCCE approach, ignores the lag value of endogenous factors (Chudik & Pesaran 2015), whereas the CCE technique considers both homogeneous and heterogeneous coefficients. The DCCE also takes into account cross-sectional dependence. This technique incorporates heterogeneous slopes and cross-sectional dependence by accounting for cross-sectional averages and lags. Furthermore, because it uses the jack-knife correction approach, this strategy works well with small sample sizes (Chudik & Pesaran 2015). The following dynamic equation was used in the study from Chudik and Pesaran (2015b):

$$REC_{it} = \delta_i REC_{it-1} + \alpha_i \omega_{it} + \sum_{p=0}^{Pr} \gamma \omega_{ip} \bar{X}_{t-p} + \sum_{p=0}^{Pr} \gamma \gamma_{ip} \bar{Y}_{t-p} + \mu_{it} \quad (12)$$

For this work, REC stands for ecological footprint, $\delta_i REC_{it-1}$ is the lag of REC, while $\alpha_i \omega_{it}$ represents the explanatory variables, and Pr refers to the limit of lags incorporated in the cross-section averages.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics and Correlation Analysis

The descriptive data and correlation analysis for the sampled 11 OPEC member countries are shown in Tables 1 and 2. Table 1 provide the description of all the variables used in this study, their units of measurement, standard deviations, means, skewness, and kurtosis in relation to the sampled economies from 1980 to 2020. The variables for this research are renewable energy consumption (REC), Financial development (FD), oil price (OILP), income (INC) and information communication technology (ICT). The Kurtosis and Skewness values present asymmetric data distribution. But if the results for Kurtosis and Skewness are 0 and 3, respectively, then indicates that the data is normally distributed. The average frequency distributions were given by the variables' Jarque-Bera statistics coefficients. The Table descriptively shows that the measure of renewable energy (REC) on average is 7.041 with a corresponding standard deviation of 4.329. Similarly, the average value of DCP as a measure of FD is 8.562 which relates to the standard deviation of 5.208, compared to the mean value 4.326 which corresponds to the standard deviation of 3.840 into the oil price. The mean value of income is 6.169, which matches the standard deviation 3.102. Notably, all the variables exhibit considerable variance between the economies, which explains why the standard deviations are smaller than the averages for the observations.

Table 2 below offers correlation coefficients for every parameter that have been employed in modelling and provides validation for the methodology choices. centered on the following correlation numbers, the study's findings indicate that none of the variables shows any indication of multi-collinearity problem among the evaluated variables.

Table 1. Descriptive Statistics Summary

| Variables | Mean | Standard deviation | Skewness | Kurtosis | Jarque-Bera |
|----------------------|-------|--------------------|----------|----------|--------------------|
| lnREC _{it} | 7.041 | 4.329 | 0.222 | 2.905 | 7.391* (0.000) |
| lnOILP _{it} | 4.326 | 3.840 | 0.121 | 2.820 | 8.327** (0.016) |
| lnFD _{it} | 8.562 | 5.208 | 0.357 | 1.849 | 15.135 (0.000) |
| lnINC _{it} | 6.169 | 3.102 | 3.205 | 2.183 | 17.705 (0.000) |
| lnICT | 7.309 | 1.357 | 0.517 | 2.301 | 16.503 (0.000) |

Table 2. Correlation Matrix Summary

| | lnREC _{it} | lnOILP _{it} | lnFD _{it} | lnINC _{it} | lnICT _{it} |
|----------------------|---------------------|----------------------|--------------------|---------------------|---------------------|
| lnREC _{it} | 1.000 | | | | |
| lnOILP _{it} | 0.227 (0.031) | 1.000 | | | |
| lnFD _{it} | 0.215 (0.000) | 0.380 (0.001) | 1.000 | | |
| lnINC _{it} | 0.320 (0.002) | 0.328 (0.011) | 0.185 (0.002) | 1.000 | |
| lnICT _{it} | 0.461 (0.004) | 0.023 (0.021) | 0.218 (0.021) | 0.329 (0.001) | 1.000 |

Note: * Shows statistical significance at 1 percent level, while ** signifies the 5 percent significance level. Source: WDI (2023); OWD (2023)

4.2 Result of Cross-section Dependence Test

By rejecting the null hypothesis at the 1% level of significance, the CD test result, computed by estimating equation (4), is displayed in Table 3 as evidence of the presence of CD in panel data. As a result, there is a significant degree of reliance across nations, suggesting that any shock to one of the growing nations will have an impact on other areas and nations.

Table 3. Cross-sectional Dependence Tests

| Variables | Pesaran's CD test | Breush-Pagan (LM) test |
|----------------------|-------------------|------------------------|
| lnREC _{it} | 4.274* (0.000) | 55.915* (0.000) |
| lnOILP _{it} | 6.691* (0.000) | 83.206* (0.000) |
| lnFD _{it} | 4.016* (0.000) | 65.183* (0.000) |
| lnINC _{it} | 5.180* (0.000) | 52.185* (0.000) |
| lnICT _{it} | 7.031* (0.000) | 73.530* (0.000) |

Note: * Shows statistical significance at 1 percent level, while ** signifies the 5 percent significance level. Source: WDI (2023); OWD (2023)

4.3 Slope Homogeneity Result

The study further assesses homogeneity in order to adequately identify the optimal panel approaches to apply. The study's homogeneity test findings are shown in Table 4 below. The analysis convincingly rejects the null hypothesis coefficients of homogeneity at a 1% significance level given the estimated values of the delta and adjusted delta and taking into account their respective P-values.

Table 4. Slope Homogeneity Tests

| Group | Statistic |
|----------------|-----------|
| Delta | 7.312* |
| Adjusted Delta | 7.971* |

Note: * Shows statistical significance at 1 percent level, while ** signifies the 5 percent significance level. Source: WDI (2023); OWD (2023)

4.4 Unit Root Result

To find a potential long-term link between the variables, it is necessary to determine the integrating qualities of the variables used in the panel (Balsalobre-Lorente et al., 2020). The CADF and CIPS unit root analyses are used to determine whether the variables REC, FD, OILP, INC, and ICT have unit roots or not. They are used to monitor the integration order and examine the potential for co-integration between the variables. The study shows the outcomes of the panel unit root tests in Table 5. The empirical findings from the CADF and CIPS tests show that these variables contain no unit root at level and first difference.

Table 5. Panel Unit Root Test

| Variables | CIPS | | CADF | |
|----------------------|--------------------|--------------------|--------------------|--------------------|
| | At level | At first different | At level | At the first diff |
| | | | Z[t-bar] | Z[t-bar] |
| lnREC _{it} | -2.712 (-2.43) | -5.172* (-2.46) | 2.674 (0.521) | -4.307* (0.000) |
| lnOILP _{it} | -3.816* (-2.43) | -6.152* (-2.45) | -3.741* (0.000) | -4.192* (0.000) |
| lnFD _{it} | -2.163* (-2.45) | -6.825* (-2.45) | -3.186* (0.000) | -5.281* (0.000) |
| lnINC _{it} | -3.284* (-2.46) | -5.624* (-2.45) | -1.184 (0.650) | -5.109* (0.000) |
| lnICT _{it} | -2.891* (-2.45) | -6.183* (-2.46) | -3.471* (0.000) | -4.325* (0.000) |

Note: * Shows statistical significance at 1 percent level, while ** signifies the 5 percent significance level. Source: WDI (2023); OWD (2023)

4.5 Co-integration Test Analysis

Westerlund cointegration test is highlighted in Table 6 below, showing the cointegration linkage between FD, OILP, INC, ICT, and REC. Based on the results at both constant and trend, the null hypothesis of no co-integration is rejected considering that the group statistics (G_t and G_α) and panel statistics (P_t and P_α) turn significant at 1 percent respectively. This implies that a long-run relationship exists between financial development, oil price, income, ICT, and renewable energy.

Table 6. Summary Results of Heterogeneous Co-integration Tests

| Statistic | with trend | without trend |
|-----------|--------------------|--------------------|
| | Value | Value |
| G_t | -3.481* (0.000) | -2.372 (1.000) |
| G_a | -8.429* (0.000) | -3.258* (0.000) |
| P_t | -5.174* (0.000) | -4.396* (0.000) |
| P_a | -4.745* (0.000) | -3.474* (0.000) |

Note: * Shows statistical significance at 1 percent level, while ** signifies the 5 percent significance level. Source: WDI (2023); OWD (2023)

4.6 Estimation Result

In empirical assessments, we used the dynamic common correlated effects approach to uncover the connection between renewable energy use and its potential drivers. Table 7 below presents the estimation outcomes of the 11 selected OPEC member economies with and without interactions (Model A and Model B). The t-statistics are contained within the square brackets. The CD Pesaran statistics and accompanying P-values that test for cross dependency in both models show that the outcomes reject the null hypothesis, confirming the high cross-sectional reliance across the sampled nations (p-value < 0.005). The value of R² which tells us the model’s goodness-of-fit reveals that the models explain 57 and 59 percent of the cross-country variations respectively. Meanwhile, the F-value 2.56 and 2.76 which display a 1 percent significance, telling us that the parameters are jointly significant.

**Table 7. Dynamic Common Correlated Effect Estimate
Dependent Variable *lnREC***

| Variables | Model A | | | Model B | | |
|------------------|-------------|----------|---------------|-------------|----------|---------------|
| | Coefficient | Std. Err | z. Statistics | Coefficient | Std. Err | z. Statistics |
| $lnREC_{it-1}$ | -0.480 | 0.120* | -3.85 | -0.006** | 0.002 | -2.58 |
| $lnOILP_{it}$ | -0.012 | 0.005** | -2.297 | 0.769* | 0.041 | 18.867 |
| $lnFD_{it}$ | 0.065 | 0.021* | 3.050 | 0.015** | 0.006 | 2.271 |
| $lnINC_{it}$ | 0.293 | 0.201 | 1.461 | 0.77* | 0.040 | 19.037 |
| $lnICT_{it}$ | 0.018 | 0.007** | 2.551 | 0.064 | 0.069 | 0.937 |
| $ln(ICT * FD)$ | - | - | - | 0.586* | 0.150 | 3.899 |
| Constant | 0.485* | 0.064 | 7.557 | 0.096 | 0.062 | 1.550 |
| Number of Groups | 11 | | | 11 | | |
| R-squared | 0.57 | | | 0.59 | | |

| | | | | |
|----------------|------|------|------|------|
| Adj. R-squared | 0.42 | | 0.45 | |
| F(94, 179) | 2.56 | 0.00 | 2.64 | 0.00 |
| CD Statistic | 2.76 | 0.00 | 3.72 | 0.00 |

Note: * Shows statistical significance at 1 percent level, while ** signifies the 5 percent significance level. Source: WDI (2023); OWD (2023)

First, Model A reveals the results of the estimation without interaction term, and based on the estimation outcomes, income appears to have no statistically significant effect on renewable energy usage. Income, which has a negligible influence, implies that these nations have failed to redirect their growing earnings away from conventional sources of energy and towards renewable energy supplies. Our findings are similar with those of Omri and Nguyen (2014) for low-income nations and Deniz (2019) for oil exporting and importing nations.

Likewise, In terms of the effect of FD on renewable energy consumption, the results indicate that FD has a positive and significant effect on renewable energy use. As such, a 1% increase in $\ln FD_{it}$ corresponds to a 0.06% increase $\ln REC_{it}$ respectively. This means that financial development promotes renewable energy usage, and the financial sectors allocates funds to cleaner energy ventures, which enhances environmentally friendly productions through the use of renewable energy sources. This is consistent with the theoretical viewpoint that financial development is projected to benefit renewable energy usage by increasing demand for environmentally acceptable energy sources by lowering renewable energy investment prices. Alongside the fact that economic growth reduces financial risk and credit costs, it could result to increased financial capital, investment flow, and improved technology, all of which have a favourable impact on the economy's energy consumption (Komal and Abbas, 2015; Ouyang and Li, 2018).

Furthermore, ICT is regarded as an important factor in the renewable energy transition; a 1% increase in ICT enhances green energy structure by 0.018%. The findings are aligned with those of Wang et al. (2021), who found that the internet drives green overall energy efficiency in China via enhanced industrial framework, innovation, and resource imbalance reduction. The positive relationship validates the importance of ICT in supporting energy transition in these oil-producing countries.

However, the result of the oil prices exerts a statistically significant and negative effect on renewable energy use. Because of the inverse elasticity of oil prices, these countries continue to benefit from high oil prices, impeding the transition from conventional to clean energy sources. In terms of sign and relevance, the current study's findings are consistent with those of Sadorsky (2009) in the context of the G7 nations, Salim and Rafiq (2012) in the event of Indonesia and China, Omri and Nguyen (2014) in the scenario of 64 nations, Deniz (2019) in the event of Azerbaijan, Mukhtarov et al. (2021) in the scenario of Kazakhstan, and Karacan et al. (2021) in the event of Russia.

On the other hand, Model B of the estimation displays the interaction term result, which discovered that financial development is a substantial positive factor of renewable energy use in our sample economies. Renewable energy consumption will be supported by the consumer effect, wealth effect, and industrial effect as financial development improves. Second, in these sample economies, ICT considerably enhances renewable energy consumption. The association between financial development and renewable energy usage is moderated by ICT. It will boost the positive influence of financial development on renewable energy usage as ICT improves.

A financial development and ICT interaction term is added to Model (B) in order to confirm the moderating influence of ICT. The estimation outcomes demonstrate a considerably positive coefficient for this interaction term, indicating a positive correlation between the interaction term and renewable energy use. ICT has a large moderating impact, one that positively modifies the link between financial development and renewable energy consumption. For every 1% rise in ICT, there will be a corresponding 0.58% positive effect of financial development in relation to renewable energy consumption. The results therefore strongly imply that ICT modifies the link between

financial development and renewable energy consumption. The development of ICT will support the positive effect of economic growth on the use of renewable energy. The outcome suggests a plan for encouraging the use of renewable energy sources by concentrating on ICT and shows that a collaborative effort between ICT and financial development on renewable energy consumption is required.

CONCLUSION

The research investigates the influence of oil prices, financial development, information and communication technology, and income in relation to renewable energy usage. The unit root tests revealed that all parameters have the same integration order ($I(1)$). As a result, one can study the likelihood of a long-term relationship. The cointegration test demonstrated that the variables move together over time. The DCCE modelling approach is used in the long-run link analysis. The results showed that rising oil prices have a negative and statistically significant impact on the consumption of renewable energy, whereas the impact of income is shown to be insignificant. That's in accordance with our study question, which aims to determine whether higher oil prices can cause these oil-rich nations to prioritize their oil exports and production at the expense of the use of renewable energy sources. However, as nations with abundant resources where oil revenues account for more than half of GDP, there is a significant chance to get and sustainably employ larger levels of oil money during rising oil prices. Given these considerations, our results of the adverse impact of higher oil prices on renewable energy use can be perceived as a failure on the part of these nations to convert increasing oil revenues during higher oil prices into more environmentally friendly and effective energy sources such as clean energy sources. In other words, based on our findings, these nations are less generous in putting funds into other forms of energy when conventional energy prices are higher. In this regard, it is suggested that increased oil profits be used to attain a suitable level of support and advancement in renewable and sustainable energy. On the contrary, the study discovered that ICT moderates the association between financial development and renewable energy consumption. The advancement of ICT will increase the positive influence of financial development on renewable energy use.

As a result, based on the lessons learned of the world's leading nations in the renewable energy sector, establishing an Energy Efficiency Fund is an efficient means of enacting energy efficiency regulations. The development of an Energy Efficiency Fund may help the relevant authorities in these economies in a variety of ways. 1) High interest rates make finance sources in these nations unreachable for renewable energy enterprises. This fund can provide long-term financing with low rates of interest to the business owners for funding investments in green energy technologies. 2) Because liberal markets tend to be more appealing to investors than dominant ones, the funding can be tasked with designing policy schemes to remove subsidies on a regular basis and to encourage competitive market fundamentals in the energy sector.

Financial development, particularly green financial development, is also becoming increasingly crucial for renewable energy use. A green finance system helps a country to build an ecologically sound renewable energy system, which greatly stimulates the usage of renewable energy. Green financial organizations should be formed in all sample nations to encourage financial activity and support environmentally beneficial projects. Furthermore, ICT encourages the growth of renewable consumption by acting as a moderator and a threshold for the positive influence of financial development on renewable energy consumption. Policymakers in the sample nations should think about fully integrating ICT with financial development and renewable energy sources.

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