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Impact of economic growth and financial development on renewable energy use in selected oil-exporting countries

Mounir Belloumi[1+]
Ahmed Aljazea[2]

[1,2]*Department of Business Administration, College of Business Administration, Najran University, Najran, Saudi Arabia.*
[1]*Email: mrbelloumi@nu.edu.sa*
[2]*Email: amaljazea@nu.edu.sa*

(+ Corresponding author)

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ABSTRACT

The aim of this study is to explore the influence of economic growth and financial development on renewable energy consumption. For the purpose of analysis, this investigation uses annual data on renewable energy consumption, economic growth, financial development, consumer price index, domestic investment, and foreign direct investment for 13 major oil-exporting countries, including Algeria, Guinea, Gabon, Iran, Libya, Nigeria, Congo, Republic of Venezuela, Saudi Arabia, Mexico, Malaysia, Sudan, and Russia, during the period 1990-2020. The study employs the Pooled Mean Group (PMG) method and Dumitrescu-Hurlin panel causality test to conduct the empirical analysis. The Hausman test determines the PMG estimator as the most suitable among the Mean Group (MG), Dynamic Fixed Effect (DFE), and PMG estimators. This research shows that economic growth and financial development have a positive and significant long-term impact on renewable energy consumption. This suggests that as the economy grows and financial systems develop, there is a potential for an increase in the use of renewable energy. The Dumitrescu-Hurlin causality test and the panel dynamic ordinary least squares (DOLS) method support these findings. From a policy standpoint, promoting economic growth and financial development could lead to greater use of renewable energy and contribute to sustainable development in oil-exporting countries.

Contribution/ Originality: This study is valuable as it focuses on the factors influencing renewable energy consumption in thirteen oil-exporting countries, examines the effects of financial development and economic growth on the use of renewable energy, and helps these countries contribute to sustainable development by increasing their use of renewable energy.

1. INTRODUCTION

For almost two centuries, the global use of fossil fuels (oil, gas, and coal) has been the dominant source of global energy consumption and supply. While fossil fuel energy consumption continues to greatly contribute to the world's economic growth, particularly for major industrialized nations, it has also significantly contributed to carbon dioxide emissions, leading to environmental degradation, climate change, and its negative effects (Cao, 2003). Carbon dioxide emissions from fossil fuels make up nearly 91% of total emissions in 2022 (The Intergovernmental Panel on Climate Change (IPCC)). Additionally, due to the non-renewable and limited nature of fossil fuels, increased energy demand can result in severe energy shortages. This poses a major problem for most countries around the world (Sun, Zhang, & Gao, 2023) hindering sustainable development. Therefore, it is essential for all countries, including oil-producing nations, to shift from non-renewable energies to renewable energies(Kahia,

Ben Jebli, & Belloumi, 2019). In this line, Nawaz and Rahman (2023) concluded that reforms in financial and institutional frameworks are strategically important for the energy transition in the Sub-Saharan Africa region.

The United Nations Environmental Protection Programme (UNEP) defines renewable energy as energy derived from sources that are naturally replenished, such as biomass, solar, wind, hydroelectric, and geothermal energy. These sources have an unlimited stock in nature and are renewed faster than they are consumed. Renewable energy is a vital and sustainable source that can help meet global energy demand, as it comes from natural sources and is constantly replenished. The adoption of renewable energy is now a crucial theme in many countries due to environmental pressures and the world's challenges in providing energy and meeting sustainable development needs. It can also improve public health, reduce environmental pollution, and reduce health costs. Investing in renewable energy can improve innovation and lead to greater sustainability (Jacobson, Delucchi, Cameron, & Mathiesen, 2018; Sovacool, 2012).

In response to these factors, many countries have implemented policies and incentives to promote the development and use of renewable energy. These policies include feed-in tariffs, tax incentives, renewable energy targets, and research and development funding. Additionally, technological advancements have made renewable energy sources more efficient and cost-effective, further driving their adoption. Because of these efforts, the share of renewable energy in total energy consumption has been steadily increasing in many countries. This transition to renewable energy not only helps to mitigate climate change and reduce environmental impact but also contributes to energy security and economic development. In conclusion, a combination of environmental, economic, and technological factors is driving the global shift towards renewable energy. As countries continue to invest in renewable energy and implement supportive policies, the share of renewable energy in total energy consumption is expected to continue to grow, leading to a more sustainable and secure energy future (Ghazouani, 2022).Saadaoui and Chtourou (2023) have presented new insights into the deployment of renewable energy in Tunisia, which appears to be an effective solution for addressing energy poverty and the challenges of climate change.

Many energy experts advocate for the use of renewable energies as an ideal solution to reduce CO2 emissions and address energy supply shortages. With advancements in technology and decreasing costs, renewable energy is becoming more accessible and feasible. Renewable energies are derived from various sources and are widely available in most countries, allowing each nation to harness its own available energy sources. Policymakers should consider the key factors that influence the use of renewable energy, with financial support being a significant driver of the industry's development. As an emerging and promising sector, the renewable energy industry requires increased domestic and foreign investments, along with efforts to lower the costs of renewable energy technologies.

Although numerous studies have explored the factors influencing the use of renewable energyuse in oil-importing countries (e.g. (Aydin & Bozatli, 2023; Ji & Zhang, 2019; Le, Nguyen, & Park, 2020; Lin & Moubarak, 2014; Nan, Huo, & Lee, 2023; Omri & Nguyen, 2014; Salim & Rafiq, 2012; Sun et al., 2023; Wen, Hong, Khalid, Mahmood, & Zakaria, 2023)), the studies on this subject for oil-exporting countries are very few (e.g. (Lahrech, Abu-Hijleh, & Aldabbas, 2023; Somoye, Seraj, Ozdeser, & Mar'I, 2023)). Thus, the main problem of this study is to explore the impact of economic growth, financial development, domestic investment, foreign direct investment (FDI) inflows, and real energy prices on renewable energy consumption in a selected group of oil-exporting countries. The importance of this paper relies on the identification of the main determinants of renewable energy in major oil exporting nations.

The objectives of this study are threefold. Firstly, it clarifies the cointegration relation between renewable energy consumption, financial development, economic growth, real energy price (proxied by the consumer price index), domestic investment, and foreign direct investment by employing the Pedroni Residual Cointegration Test. Secondly, it examines the impact of the different independent variables, mainly financial development and economic growth, on renewable energy consumption in both the short run and long run using the PMG, MG, and DFE estimators. The DOLS method will be used to verify the robustness of results. Thirdly, the Dumitrescu-Hurlin

(DH) panel causality test is employed to investigate the various directions of causality between renewable energy consumption and the independent variables.

The uniqueness of this study has two aspects. Firstly, in contrast to most literature, the analysis not only focuses on a single determinant of renewable energy use but also on various determinants such as financial development, economic growth, consumer price level, domestic investment, and FDI. It is thus interesting to analyze the effects of different independent variables on renewable energy consumption to help decision makers understand the underlying factors affecting renewable energy use and take steps to promote the widespread adoption of this resource and, thus, sustainable development. Secondly, unlike previous studies that focused on oil-importing countries, our work is one of the first to explore the influence of economic output and financial development on the use of renewable energies in a selected sample of thirteen oil-exporting countries.

The remainder of the paper is organized as follows: Section 2 reviews recent studies on the determinants of renewable energy consumption. Section 3 presents the data and the various econometric methods used. Section 4 reports the different empirical findings, while Section 5 discusses the results. In Section 6, the robustness of the findings is checked. Finally, Section 7 concludes the study by presenting the most important findings and policy implications.

2. LITERATURE REVIEW

Research on non-renewable energy consumption has grown rapidly in the past three decades, while studies on renewable energy consumption have only recently gained attention. Sadorsky (2009a) examined the relationship between income and renewable energy use in 18 emerging countries and found that increased gross domestic product (GDP) leads to an increase in the use of renewable energies. Similarly, Sadorsky (2009b) investigated the factors influencing the use of renewable energies in G7 economies and found that output growth and carbon emissions have a positive impact on long-term renewable energy consumption, while the impact of oil prices is negative. Apergis and Payne (2010) explored the dynamic relationships between output growth and renewable energy use in Organization for Economic Co-operation and Development (OECD) economies and revealed a long-term relationship and a bidirectional link between the two variables in both the short- and long-term. Salim and Rafiq (2012) studied the determinants of renewable energy use in emerging economies and found that GDP and carbon emissions are the main explanatory factors of renewable energy use in China, Indonesia, Brazil, and India, while only income affects the use of renewable energies in Turkey and the Philippines.

Lin and Moubarak (2014) studied the link between renewable energy use and economic growth in China from 1977 to 2011. They found that economic growth contributes to increased use of renewable energies in China. Omri and Nguyen (2014) analyzed the factors influencing renewable energy use in 64 countries from 1990 to 2011. They concluded that carbon emissions and international trade are the main factors influencing renewable energy use. Doytch and Narayan (2016) investigated the impact of detailed FDI flows on renewable and non-renewable industrial energy sources in 74 countries from 1985 to 2012. They found that disaggregated FDI inflows increase renewable energy sources. Lee and Jung (2018) utilized the Autoregressive Distributed Lag approach (ARDL) model and causality tests to demonstrate that output growth drove renewable energy usage in South Korea from 1990 to 2012. Paramati, Ummalla, and Apergis (2016) examined the impact of economic growth and foreign capital on renewable energy consumption in 20 emerging economies from 1991 to 2012 using panel econometric techniques. They discovered that the three independent variables positively influence clean energy use in the long run. Lastly, Matei (2017) investigated the relationship between renewable energy usage and output growth in 34 OECD economies from 1990 to 2014 using panel cointegration techniques. Their results indicated that real GDP growth has a positive long-term effect on renewable energy usage but a negative short-term effect.

Numerous previous studies have shown that financial development is a key driver of renewable energy development. Financial institutions can provide funding for renewable energy projects, and the stock market

can finance environmentally friendly industries related to renewable energies (Anton & Nucu, 2020; Lahiani, Mefteh-Wali, Shahbaz, & Vo, 2021). Empirical studies have confirmed that financial development can lead to increased use of renewable energies. For example, Kutan, Paramati, Ummalla, and Zakari (2018) examined the impact of stock exchange development on renewable energy use in five emerging countries, finding that stock exchange development can promote renewable energy use. Ji and Zhang (2019) found that financial development significantly contributed to the growth of renewable energy use in China, with the capital market playing a crucial role. Eren, Taspinar, and Gokmenoglu (2019) studied the influence of financial development and GDP growth on renewable energy use in India, finding that both factors affect renewable energy use. Qamruzzaman and Jianguo (2020) found an asymmetric long-term relationship between renewable energy use, financial development, international trade, and capital flows in low-income, middle-income, and upper-middle-income countries. Similarly, Lahiani et al. (2021) studied the impact of financial development on renewable energy use in the U.S., finding that variations in financial development affect renewable energy consumption.

Alsagr and Van Hemmen (2021) investigated the effects of geopolitical risk index and financial development on renewable energy use in nineteen emerging economies, reporting that financial development facilitates the shift to renewable energy usage. Khan, Chenggang, Hussain, and Kui (2021) analyzed the effects of technological innovation, financial development, economic growth, and FDI inflows on renewable energy use in sixty-nine economies, finding that financial development has a positive impact on renewable energy use. Shahbaz, Topcu, Sarıgül, and Vo (2021) studied the long-term effect of financial development on renewable energy use in thirty-four upper-middle-income economies, finding a positive and significant impact of financial development on renewable energy use. Somoye et al. (2023) analyzed the influence of financial development on Nigeria's renewable energy use, finding a negative effect on renewable energy use at lower and higher quantiles. Sun et al. (2023) explored the influence of financial development on renewable energy use in 103 developed and developing countries, finding a positive impact of financial development on the consumption of renewable energy resources. Additionally, financial development could lead to the promotion of renewable energy use in developed countries more than in developing ones.Lahrech et al. (2023) concluded that increased use of renewable energy will reduce future economic growth in Gulf Cooperation Council countries.

Murshed and Tanha (2021) examined the asymmetric relationship between renewable energy use and oil prices in a panel of net oil-importing-countries from South Asia during 1990-2018. Their findings suggested that higher oil prices facilitate renewable energy use when they surpass the oil price threshold (US $135). Fang, Yang, Tian, and Ma (2022) considered another significant factor that could enhance the use of renewable energies. They investigated the impact of environmental taxes on renewable energy use in a panel of 15 nations selected along the Belt and Road using a panel ARDL model over the period 1998-2019. Their results revealed that environmental taxation has a positive impact on long-term renewable energy use, while its short-term effect is negative. Similarly, Aydin and Bozatli (2023) examined the effects of environmental taxes on renewable energy use using symmetrical and asymmetrical panel ARDL models in the top 10 renewable energy-using countries of the OECD for the period 1994 to 2019.-Overall, their findings suggested that environmental taxes could be an effective tool for promoting the consumption of renewable energies. Chu, Doğan, Ghosh, and Shahbaz (2023) corroborated these findings when they analyzed the effects of various factors on renewable energy use, such as environmental policies, economic growth, geopolitical risk, oil prices, CO2 emissions, and population, in 30 high- and middle-income economies during the period 1990-2018.

Gozgor, Mahalik, Demir, and Padhan (2020) conducted a study on the impact of economic globalization on renewable energy consumption in 30 OECD nations from 1970-2015 using various panel econometric methods. They discovered that factors such as globalization, oil prices, per capita income, and per capita carbon dioxide emissions all contribute to the use of renewable energies. Zhang, Zhang, Lee, and Zhou (2021) also researched the impact of international trade openness on renewable energy use in 35 OECD nations from 1999-2018, finding

that imports, exports, and global international trade all have a positive effect on the use of renewable energies. Ozcan and Temiz (2022) explored the impact of globalization on renewable energy use in Turkey from 1980-2017, concluding that globalization has a positive impact on renewable energy use and that increases in human capital stock and GDP growth also promote renewable energy use. Tan and Uprasen (2022) studied the impact of FDI inflows on renewable energy use in BRICS countries from 1990-2015, finding that FDI can promote renewable energy use if the stringency exceeds a certain threshold. However, Elheddad, Alfar, Haloub, Sharma, and Gomes (2022) showed that FDI inflows discourage the use of renewable energies in Bangladesh. Wen et al. (2023) studied the effect of financial development and foreign capital on renewable energy use in 17 developing countries from 1990-2020, finding that both factors have had a positive impact on the use of renewable energies in the sub-samples of countries examined. Nan et al. (2023) investigated the effect of globalization on renewable energy use in 60 countries from 1995-2018, finding that international cooperation boosts the shift to renewable energy usage and stimulates its development.

Subramaniam, Masron, and Loganathan (2023) recently examined another potential factor influencing the use of renewable energy. The authors employed the ARDL model to analyze the impact of remittances on renewable energy use in a group of developing nations that are major recipients of remittances, covering the years 1990-2016. Their results indicated that remittances can encourage the consumption of renewable energy. Crichton, Mette, Tambo, Nduhuura, and Nguedia-Nguedoung (2023) discovered that a climate strategy focused on environmental governance and policy discourse promotes the use of renewable energies in Austria. Additionally, Han, Zakari, Youn, and Tawiah (2023) examined the connection between natural resources and the utilization of renewable energy in a group of 162 developed and developing economies during the period of 1990 to 2021, finding a positive link between both variables. These results imply that the extraction of natural resources can stimulate the consumption of renewable energy. Zhao, Li, and Mehmood (2023) analyzed yearly aggregate and disaggregated data from 1990 to 2020 for G11 countries and found that innovations, human capital, and energy prices contribute to the use of renewable energies. In their study, Chu, Ghosh, Doğan, Nguyen, and Shahbaz (2023) examined how energy security risks and economic complexity influence the adoption of renewable energy sources in the 23 most energy-consuming countries from 1997-2017, concluding that economic complexity has mixed impacts on renewable energy use, while an increase in the energy security risk index may lead to greater use of renewable energies. Using the same technique, Chu (2023) explored the effects of energy security and economic complexity on the utilization of renewable energy in G-7 nations during the period of 1980 to 2017, finding that energy insecurity may drive the advancement of renewable energy, while economic complexity may impede its progress.

Analysis has identified various ways in which economic growth and financial development can promote the use of renewable energy. Empirical studies have also shown evidence of these relationships. Nevertheless, some researchers have reported conflicting results on the relationship between financial development and renewable energy use, indicating that the connection between the two is intricate and has many aspects.

The literature on energy has made significant progress in developing the theory that provides a foundation for exploring the relationship between economic growth, financial development, and renewable energy consumption. This empirical evidence can help guide energy policy decisions for different economies. However, there are several limitations in the existing literature. Most scholars have focused on oil-importing countries, and few have considered the major oil-exporting countries. Additionally, the use of different methods and data makes it challenging to conduct comparative analyses of different studies. Furthermore, while some scholars have recognized the importance of considering multiple determinants of renewable energy consumption, many studies have only used a single or a few determinants of renewable energy consumption. Hence, this work aims to analyze the influence of financial development and economic growth on renewable energy consumption by including three

control variables (consumer price index, Gross fixed capital formation, and foreign direct investment) in a selected group of major oil-exporting countries, in order to contribute to the empirical understanding of this subject.

3. RESEARCH METHODOLOGY

This part of the paper begins by presenting the variables and then discussing the various econometric techniques employed to study the influence of financial development and GDP growth on renewable energy consumption in thirteen chosen oil-exporting countries. The selection of variables and countries for the study is dependent on the availability of the data and the study's objectives. Our model includes six variables: one explained variable, two explanatory variables, and three control variables. The explained variable is renewable energy use (REU). GDP growth and financial development are the main independent variables, while the consumer price index (proxy of energy price), FDI inflows, and gross fixed capital formation (proxy of domestic investment) are used as control variables. Data for the different time series were collected for the period 1990-2020 for 13 oil-exporting economies, including Algeria, Guinea, Gabon, Iran, Libya, Nigeria, Congo, Republic of Venezuela, Saudi Arabia, Mexico, Malaysia, Sudan, and Russia. The data used in this study was collected from the online World Bank Database's World Development Indicators (WDI, 2022). Table 1describes the different series and their corresponding data sources.

Table 1. Nature and data sources of the variables.

Variable notation	Variable	Definition and nature	Source
REU	Renewable energy use	It represents the consumption of renewable energies as a share of total final energy use	WDI online database of the WDI (2022)
GDPCG	GDP per capita growth	It indicates the yearly increase in GDP per capita.	
CPI	Consumer price index	It measures average price change over time for a group of consumed goods and services	
FD	Domestic credit to private sector	It represents the financial resources provided by companies and financial organizations to the private sector as a percentage of the GDP	
DI	Gross fixed capital formation	It is the gross domestic fixed investment expressed as a share of the GDP	
FDI	Net inflows of foreign direct investments	It refers to the new investment inflows minus divestment in the host economy divided by GDP	

In order to analyze the impact of GDP growth and financial development on renewable energy consumption in oil-exporting countries, the panel ARDL approach is used. This involved four steps. First, cross-sectional dependence in the variables is checked. Second, panel unit root tests are conducted to determine the order of integration of the series.

There are two types of PUR tests, one that assumes sectional independence and the other that assumes cross-sectional dependence. Table 2 presents the various PUR tests. Third, Pedroni cointegration tests are employed to check for cointegration among the variables. Finally, the panel ARDL model is estimated using the PMG estimator to explore the short-and long-term impact of GDP growth and financial development on renewable energy consumption in 13 oil-exporting economies.

Table 2. Panoply of PUR tests.

First group of PUR tests		Second group of PUR tests	
Null hypothesis assumes the non-stationarity	Null hypothesis assumes stationarity	Null hypothesis assumes the non-stationarity	Null hypothesis assumes stationarity
Test of Maddala and Wu (1999)	Test of Hadri (2000)	Test of Chang (2002)	Test of Bai and Ng (2005)
Test of Breitung (2000)		Test of Moon and Perron (2004)	Test of Harris and Tzavalis (1999)
Test of Choi (2001)		Test of Bai and Ng (2004)	
Test of Levin, Lin, and Chu (2002)		Test of Pesaran (2007)	
Test of Im, Pesaran, and Shin (2003)			

Source: Tugcu (2018).

The econometric model linking renewable energy use to the different independent variables considered takes the following form:

$$REU_{it} = \beta_0 + \beta_1 GDPCG_{it} + \beta_2 FD_{it} + \beta_3 CPI_{it} + \beta_4 DI_{it} + \beta_5 FDI_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

Where the index $i (i = 1, 2, \dots, 13)$ represents the oil-exporting countries included in the study; t $(t = 1990, \dots, 2020)$ indicates the periods. It is observed that the number of years is greater than the number of countries, which implies that the panel is heterogeneous. Moreover, when the variables are only integrated of order 0 or 1, the model is dynamic and consequently, the panel ARDL model is appropriate to be considered here.

Therefore, Equation 1 may be written in the upcoming panel ARDL model (p, q) specification:

$$REU_{it} = \alpha_0 + \sum_{j=1}^{p} \alpha_{ij} REU_{i,t-j} + \sum_{j=0}^{q} \beta_{ij} GDPCG_{i,t-j} + \sum_{j=0}^{q} \nabla_{ij} FD_{i,t-j} + \sum_{j=0}^{q} \theta_{ij} CPI_{i,t-j} + \sum_{j=0}^{q} \eta_{ij} DI_{i,t-j} + \sum_{j=0}^{q} \upsilon_{ij} FDI_{i,t-j} + \mu_i + \varepsilon_{it} \quad (2)$$

Then, Equation 2 is transformed into the error correction specification:

$$\Delta REU_{it} = \alpha_0 + \Phi_i ECT + \sum_{j=1}^{p-1} \alpha_{ij} \Delta REU_{i,t-j} + \sum_{j=0}^{q-1} \beta_{ij} GDPCG_{i,t-j} + \sum_{j=0}^{q-1} \nabla_{ij} FD_{i,t-j} + \sum_{j=0}^{q-1} \theta_{ij} CPI_{i,t-j} + \sum_{j=0}^{q-1} \eta_{ij} DI_{i,t-j} + \sum_{j=0}^{q-1} \upsilon_{ij} FDI_{i,t-j} + \mu_i + \varepsilon_{it} \quad (3)$$

Where $ECT = (REU_{it-1} - \gamma_i' X_{it})$ is the error correction term; X represents the independent variables (GDPCG, FD, CPI, DI, FDI); γ_i' is the vector of long run coefficients that measure the impact of independent variables on renewable energy consumption in the long term; Φ_i is the group-specific coefficient of speed of adjustment $(\Phi_i < 0)$; p and q are the optimal lag orders; α_{ij}, β_{ij}, ∇_{ij}, θ_{ij}, η_{ij}, *and* υ_{ij} are the coefficients of short-run dynamic coefficients; μ_i is the individual effects; and ε_{it} are error terms.

Employing the MG, PMG, and DFE estimators allows for the estimation of the model in Equation 3. All three estimators take into account slope heterogeneity and CS interdependence. Then the PMG Hausman test is used to determine the best estimator among the three. According to the decision rule of this test, if the null hypothesis (H0) is accepted, the PMG estimator is more reliable than the alternative (MG or DFE). Finally, the results of the chosen estimator are analyzed and interpreted based on the outputs of the Hausman test.

4. EMPIRICAL RESULTS

Table 3 shows the descriptive statistics for the various time series under investigation. The average total of the REU variable in the selected sample of countries during the study period is 32.423%, while globally it is 17.357% for the same period (WDI, 2022). This indicates that the levels of renewable energy use in some oil-exporting nations are significant. The share of renewable energy consumption varies across nations, ranging from 1% to 90%. Table 4 displays the results of the correlation matrix and the variance inflation factor (VIF) test. Overall, the results indicate a satisfactory level of correlation among the different explanatory variables. The

correlation coefficients between all independent variables have absolute values ranging from 0.002 to 0.365. Additionally, VIF coefficients are all less than 10 for all variables, indicating the absence of multicollinearity issues. Therefore, all independent variables (per capita GDP growth, CPI, FD, FDI, and DI) are retained for further analysis as explanatory factors of renewable energy use in oil-exporting countries.

Table 3. Descriptive statistics.

Variables	REU	GDPCG	FD	CPI	DI	FDI
Mean	32.423	0.850	26.228	160.346	23.868	2.304
Median	10.270	1.496	15.765	85.236	22.058	1.371
Maximum	90.120	96.956	158.505	3538.69	81.021	39.810
Minimum	0.010	-47.899	1.615	0.053	5.539	-18.917
Std. dev.	35.820	7.437	30.136	428.470	9.022	4.389
Observations	403	403	403	403	403	403

Source: WDI (2022) data.

Table 4. Results of correlation matrix and VIF test.

Variables	GDPCG	FDI	FD	CPI	DI	VIF
GDPCG	1.000	-	-	-	-	2.689
FDI	0.014	1.000	-	-	-	2.769
FD	0.048	0.039	1.000	-	-	4.468
CPI	-0.124	-0.027	0.002	1.000000	-	6.910
DI	-0.052	0.365	0.106	-0.075	1.000	7.544

Source: WDI (2022) data.

The empirical analysis starts by examining the variables for the presence of CD and then conducting PUR tests.Table 5 displays the results of CD tests. Overall, the results of Pesaran CD test suggest the acceptance of the null hypothesis of no CD, leading us to conclude the existence of CS dependence in all the series. These results suggest that any change in any independent variable affecting renewable energy consumption in one country could also affect renewable energy use in other oil-exporting nations. Consequently, the first group of PUR tests cannot be used to verify the stationarity of the variables under investigation. Nevertheless, the absence of unit roots in the different series with CD can be checked using the second-generation of PUR tests. The Im-Pesaran-Shin unit-root (CIPS) test (Im et al., 2003)is employed to examine the stationarity of series with CD. The test is conducted for the levels and first differences of the various variables. Table 5 presents the results of CIPS test. It is shown that GDPCG and DI are stationary at their levels in the presence of CD, while the variables REC, FD, CPI, and FDI are integrated of order one. Hence, there is a combination of integrated series of order 0 and 1. Consequently, the panel ARDL model is estimated.

Table 5. Results of CD and stationary tests.

Variables	Pesaran CD test	Cross-sectional Im-Pesaran-Shin (CIPS) test		Integration order
		On level	On first difference	
REU	6.95***	-1.07	-3.09***	I(1)
GDPCG	6.35***	-3.34*	-4.64***	I(0)
DI	2.23**	-2.65*	-2.70***	I(0)
FDI	4.82***	-2.16	-5.319***	I(1)
CPI	32.88***	-0.36	-27.24***	I(1)
FD	14.97***	-1.63	-5.43***	I(1)

Note: For the Pesaran CD test, the null hypothesis assumes no cross-section dependence. For the CIPS test, the null hypothesis assumes unit root process. ***: Significant at the 1% significance level, **: Significant at the 5% significance level, *: Significant at the 10% significance level.

The Pedroni cointegration test is used to examine the cointegration relationship between the dependent variable (REU) and the independent variables (GDPCG, FD, CPI, FDI, and DI). The panel ARDL model is then

estimated. Table 6 presents the findings of the Pedroni cointegration tests. The Phillips-Peron (PP) test-statistic and Augmented Dickey Fuller (ADF) test-statistic show that the null hypothesis (H0) is not true at 5% and 10% significance levels. This is true for both panels and groups. Therefore, it can be deduced that there is cointegration relationship between REU, GDPCG, CPI, FD, DI, and FDI in the selected panel of oil-exporting nations under investigation.

Table 6. Results of Pedroni cointegration test.

Tests	Statistic	Prob.
Panel v-statistic	-4.24	1.00
Panel rho-statistic	0.67	0.74
Panel PP-statistic	-1.58**	0.05
Panel ADF-statistic	-1.56**	0.05
Group rho-statistic	3.41	0.99
Group PP-statistic	-1.66**	0.04
Group ADF-statistic	-1.26*	0.10

Note: **: Significant at the 5% significance level, *: Significant at the 10% significance level.

After establishing that the variables are cointegrated, the PMG Hausman specification test is conducted to determine the most suitable estimation method for estimating the long- and short-term coefficients among PMG, MG, and DFE.

The results of this test can be found in Table 7. The results of the Hausman test show a p-value of 0.54 when comparing MG to PMG. As a result, the null hypothesis is accepted, indicating that the PMG estimator fits better. In the same way, when comparing PMG to the DFE model, the PMG estimator is once again chosen because of the p-value of 0.90 associated with H0. Therefore, PMG is deemed the best estimator. Consequently, our model permits heterogeneous short-run coefficients with common long-run effects.

Table 7. PMG Hausman test results.

H0: The estimator is comparable to the PMG		
Estimator	**Statistic**	**Prob.**
Mean group	4.024	0.54
Dynamic fixed effects	1.601	0.90

As the PMG estimator better fits the model, its results are considered in Table 8. It is shown that the variables of GDP growth, financial development, and consumer price index have positive and significant long-run coefficients (GDPCG, CPI, and FD) at 1% and 5% levels.

These findings suggest that an increase in GDP growth will lead to a higher share of renewable energy use in the long run for oil-exporting nations. Additionally, financial development has a positive impact on renewable energy use in the long-term, highlighting the crucial role of financial sector development in promoting renewable energy use in oil-exporting countries. However, both DI and FDI are not significant in explaining renewable energy consumption in oil-exporting economies.

The results of error correction term in Table 8 indicate a negative and significant coefficient (-0.229) at the 1% level, confirming the presence of cointegration among renewable energy use and the explanatory variables for oil-exporting nations.

In the short term, only the variable GDPCG has a significant negative coefficient, while the variables FD, CPI, DI, and FDI are not significant.

Table 8. PMG-ARDL long run and short run estimates.

Variable	Coefficient	Std. error	t-statistic	Prob.
Long-run (Pooled) coefficients				
GDPCG	0.033***	0.010	3.179	0.001
FDI	0.023	0.015	1.590	0.112
FD	0.017***	0.004	3.699	0.000
CPI	0.001**	0.0008	2.434	0.015
DI	0.001	0.0065	0.305	0.759
@TREND	-0.042***	0.007	-5.332	0.000
Short-run (Mean-group) coefficients				
COINTEQ	-0.229***	0.068	-3.355	0.000
D(GDPCG)	-0.060**	0.028	-2.117	0.034
D(GDPCG(-1))	-0.031	0.037	-0.829	0.407
D(GDPCG(-2))	0.062*	0.037	1.669	0.095
D(FD)	-0.026	0.088	-0.295	0.767
D(CPI)	0.063	0.084	0.755	0.450
D(DI)	0.010	0.034	0.320	0.748
D(DI(-1))	-0.026	0.020	-1.313	0.189
D(DI(-2))	-0.040	0.048	-0.835	0.404
C	4.916***	1.904	2.581	0.010
Log-Likelihood:	-181.382			

Note: GDPCG: GDP per capita growth; FDI:Foreign direct investment; FD: Financial development; CPI: Consumer price index; DI: Domestic investment; @TREND: Trend; COINTEQ: Error correction term; D(GDPCG): First difference of GDPCG; D(GDPCG(-1)): Second difference of GDPCG; D(GDPCG(-2)): Third difference of GDPCG; D(FD): First difference of FD; D(CPI): First difference of CPI; D(DI): First difference of DI; D(DI(-1)): Second difference of DI; D(DI(-2)): Third difference of DI; c: Constant. The selected model is PMG (1,3,0,1,1,3); ***: Significant at the 1% significance level, **: Significant at the 5% significance level, *: Significant at the 10% significance level.

Finally, the causal relationship between REC, GDPCG, FD, CPI, FDI, and DI is examined using the DH panel causality test. Its results are particularly useful when there is slope heterogeneity and CD among the countries being studied (Bhujabal, Sethi, & Padhan, 2021). Table 9 reports the results of this test, which accounts for heterogeneity. The study demonstrates a two-way relationship between renewable energy use and the consumer price index, a one-way relationship from financial development to renewable energy consumption, and a one-way relationship from renewable energy consumption to domestic investment. There is no proof of a causalityfrom economic growth, domestic investment, and FDI to renewable energy use across countries. These causality results support the PMG long-run coefficients for the variables FD, CPI, FDI, and DI.

Table 9. Results of DH panel causality test.

H_0	W-statistic	Zbar-statistic	Prob.	Decision
FD does not cause REU	5.503	2.561	0.010	H_0 is rejected
REU does not cause FD	3.864	0.642	0.520	H_0 is accepted
FDI does not cause REU	3.914	0.700	0.483	H_0 is accepted
REU does not cause FDI	4.032	0.839	0.401	H_0 is accepted
GDPCG does not cause REU	2.575	-0.866	0.386	H_0 is accepted
REU does not cause GDPCG	3.374	0.068	0.945	H_0 is accepted
DI does not cause REU	4.576	1.475	0.140	H_0 is accepted
REU does not cause DI	5.209	2.216	0.026	H_0 is rejected
CPI does not cause REU	6.136	3.302	0.001	H_0 is rejected
REU does not cause CPI	5.382	2.419	0.015	H_0 is rejected

5. DISCUSSION

This work analyzes the influence of GDP growth and financial development on renewable energy use in a group of 13 oil-exporting countries. After verifying that the series are cointegrated, the PMG Hausman test is carried out to identify the most suitable estimation method for assessing the long-and short-term coefficients among PMG, MG, and DFE. The test results show that the PMG estimator is the most appropriate of the three estimators.

The findings from the PMG estimator reveal that economic growth, financial development, and CPI have positive and significant long-run effects on renewable energy use. This suggests that an increase in economic growth will lead to a higher share of renewable energy use in the long run for oil-exporting nations. These findings are in line with earlier studies by Sadorsky (2009a) and Sadorsky (2009b); Salim and Rafiq (2012); Lin and Moubarak (2014); Paramati et al. (2016) and Matei (2017). Furthermore, financial development has a long-term positive and significant impact on the use of renewable energy, underscoring the important role of the financial sector in promoting renewable energy use in oil-exporting countries. This finding aligns with previous empirical studies by Kutan et al. (2018); Ji and Zhang (2019); Eren et al. (2019); Qamruzzaman and Jianguo (2020); Lahiani et al. (2021); Alsagr and Van Hemmen (2021); Shahbaz et al. (2021) and Sun et al. (2023). However, domestic investment and FDI have no significant influence on renewable energy use in oil-exporting countries, indicating that these types of investments are insufficient to enhance renewable energy use in these nations. In the short run, only economic growth has an unexpected negative impact on renewable energy use in the selected oil-exporting nations. This result is in line with the findings of Matei (2017). The association between fossil fuels and GDP growth could be the reason for the slow development of renewable energies in these nations (Alshehry & Belloumi, 2014).

6. ROBUSTNESS CHECK

To estimate long-term coefficients, various standard econometric techniques are utilized. Therefore, the DOLS method, originally developed by Mark and Sul (2003), is used to assess the robustness of the PMG estimates. The DOLS estimation method was chosen because it is suitable for small samples and effectively addresses CD and heterogeneity in data. By choosing lead and lag variables when estimating the model, the DOLS method also get gets rid of the effects that endogeneity and correlation might have on the residuals. Thus, the DOLS estimator is unbiased. The results of the DOLS estimation method are reported in Table 10. As indicated in Table 10, the three variables representing GDP growth, financial development, and CPI have a positive impact on renewable energy use in oil-exporting nations, while the variables of domestic investment and FDI have a positive effect but are not significant. Furthermore, the adjusted R-squared value is very high (0.995). These findings align with those of long run PMG estimates. Hence, it can be inferred that the findings of the PMG method are reliable.

Table 10. Results of panel dynamic least squares (DOLS).

Variable	Coefficient	Std. error	t-statistic	Prob.
FD	0.040***	0.015	2.600	0.01
FDI	0.023	0.118	0.197	0.84
GDPCG	0.052*	0.032	1.640	0.10
DI	0.021	0.035	0.606	0.54
CPI	0.003**	0.001	2.225	0.02
R-squared		0.999		
Adjusted R-squared		0.995		

Note: ***: Significant at the 1% significance level, **: Significant at the 5% significance level, *: Significant at the 10% significance level.

7. CONCLUSION

This paper analyzes the impact of GDP growth and financial development on renewable energy use in a group of 13 oil-exporting economies during the period 1990-2020. The analysis includes other macroeconomic variables such as the consumer price index, domestic investment, and FDI inflows as control variables. A range of panel econometric methods, such as the Pesaran CD test, CIPS test, Pedroni residual cointegration test, PMG Hausman test, PMG estimator, MG estimator, DFE estimator, and Dumitrescu-Hurlin causality test, are employed to assess the short- and long-term impacts of the independent variables on renewable energy use. The results of the Pedroni residual cointegration test show that there is a cointegration relationship between renewable energy use and its

determinants (output growth, financial development, consumer price index, domestic investment, and foreign direct investment inflows). The PMG estimates reveal that economic growth, financial development, and consumer price index have positive impacts on renewable energy use in the selected sample of oil-exporting economies. Overall, the results indicate that output growth significantly enhances long-term renewable energy use, but has a negative effect in the short run. This long-term positive impact of GDP growth on renewable energy use is in line with previous studies (e.g. (Chu, Doğan, et al., 2023; Eren et al., 2019; Gozgor et al., 2020; Lee & Jung, 2018; Lin & Moubarak, 2014; Matei, 2017; Sadorsky, 2009a, 2009b; Salim & Rafiq, 2012)). Additionally, the findings show that financial development promotes the use of renewable energies in the long run among oil-exporting countries, which aligns with the results of many earlier research studies, such as those of Kutan et al. (2018); Ji and Zhang (2019); Eren et al. (2019); Qamruzzaman and Jianguo (2020); Lahiani et al. (2021); Alsagr and Van Hemmen (2021); Shahbaz et al. (2021), and Sun et al. (2023).

Our ongoing research has significant implications for the countries studied in pursuit of securing renewable energies. The findings indicate that oil-exporting countries, with their ample finances and high GDP growth rates, are increasingly turning to renewable energy. Therefore, in order to achieve key objectives such as widespread use of renewable energies, it is crucial to strengthen the development of financial resources and long-term GDP growth in these countries.

Based on our findings, decision-makers in oil-exporting economies should increase the share of renewable energy in total final energy consumption to diversify their economic activities and achieve sustainable development goals. Given the diminishing oil supply and the need to reduce the carbon emissions from burning fossil fuels, the production and consumption of renewable energies must be given top priority. Some oil-exporting countries, such as Algeria, Libya, Nigeria, Saudi Arabia, and Russia, have significant potential in renewable and non-renewable sources of energy. Nevertheless, as the depletion of fossil fuels looms and global demand shifts towards renewable energies, these countries will lose their advantage. Therefore, oil-exporting nations need to focus on investing in renewable energy projects. Additionally, the majority of oil-exporting countries is major contributors to CO_2 emissions and thus plays a role in global warming. To address climate change, the use of non-renewable energies must be reduced. By transitioning from fossil fuels to renewable energies, oil-exporting nations can greatly contribute to combating climate change. Furthermore, if these countries, which also have significant potential for renewable energy sources, embrace this direction, they can also be instrumental in the advancement of renewable energy.

Due to a lack of data for some macroeconomic variables and countries, this work is only able to use annual data for 13 major oil-exporting nations. Future research on this topic could explore the inclusion of additional variables in the model, such as geopolitical risk index and oil price volatility. Despite these limitations, our findings are still valuable and relevant for the selected oil-exporting countries.

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