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Investigating the Symmetric and Asymmetric Impacts of Oil Price Fluctuations on Green Energy Transition in Oil-Exporting and Oil-Importing Countries

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ABSTRACT

This research explores the repercussions of oil price on green energy transition across a panel of oil-exporting and oil-importing nations between 2000 and 2020. Employing a wide range of second-generation panel data techniques, specifically the PMG-ARDL framework, the research examines the symmetric and asymmetric repercussions of oil price, research and development expenditures, GDP, and GHG emissions on energy transition. The symmetric analysis indicates a positive connection between oil price and energy transition in the full sample and both sub-samples, with a stronger impact observed in oil-exporting nations. Furthermore, research and development expenditures, GHG emissions, and GDP positively influence green energy transition in the long-term. The asymmetric analysis reveals some new findings since it suggests that only oil price increases positively drive green energy transition in the long-run, while price decreases show no significant impact. This asymmetry holds across the full sample and both country groups. However, the positive influence of oil price increases on green energy transition is more apparent in oil-exporting nations. These findings carry significant policy implications for formulating targeted recommendations aimed at achieving a net-zero economy and promoting environmental sustainability.

Keywords: Oil Price, Energy Transition, Environmental Sustainability, Pooled Mean Group-Autoregressive Distributed Lag, Asymmetry
JEL Classifications: O13, P28, C23, Q42

1. INTRODUCTION

A global effort to promote the shift towards clean energy sources has recently occurred, motivated by concerns regarding various factors, including energy security, environmental sustainability, and climate change (De La Peña et al., 2022; Rabbi et al., 2022; Aslam et al., 2024; Cheikh and Zaied, 2024). Oil has historically exerted substantial repercussions on the economy. Oil prices variations have been shown to impact macroeconomic stability, industrial production, and transportation costs on a global scale (Zmami and Ben-Salha, 2020; Baek, 2021; Ayad et al., 2023; Shang and Hamori, 2024; Liang et al., 2025; Zhao et al., 2025). Nevertheless, the pressing need to reduce CO_2 emissions from conventional energy systems and the fluctuations of fossil fuels, mainly oil, has led to a pronounced effort to promote green energy. With reference to this issue, Hammoudeh et al. (2021) indicated that the share of oil in total energy use has declined in recent decades. Ath the same time, the share of renewable energy sources increased, particularly hydropower, solar and wind. According to the Energy Institute (2020), hydropower represented 6.45% of global energy mix in 2019, while solar and wind represented together about 3.3%. The complex interactions between brown energy, especially oil, and the growing renewable energy sector is of great importance for the energy transition process.

This research explores the linkages between oil price and the green energy transition. In particular, the analysis explores the symmetric and asymmetric repercussions of oil price on green energy transition in oil-exporting and oil-importing nations from 2000 to 2020. An examination of the interrelationships between oil prices and energy transition is imperative for several reasons. First, the economic competitiveness of renewable energy projects is influenced by oil price fluctuations (Heal and Hallmeyer, 2015; Hsiao et al., 2019; Sorokin et al., 2023; Tambari et al., 2023). On the one hand, a rise in oil prices encourages renewable energy investment in which become more cost-effective than fossil fuel projects. On the other hand, a decline in oil price diminishes the interest in green energy projects, thereby increasing fossil fuel consumption and reducing the demand for clean energy. Second, the sharp volatility of oil prices experienced during the latest decades has introduced significant uncertainty into energy markets (Dutta, 2017; Xu et al., 2021; Lyócsa and Todorova, 2024). This uncertainty may negatively long-term investment not only in traditional fossil fuel projects, which becomes riskier with fluctuating profitability, but also in renewable energy projects, as their competitiveness can be influenced by sharp declines in oil prices.

This paper enhances the literature through the following key contributions. First, the study conducts a disaggregated analysis of the repercussions of oil price on green energy use by considering both oil-importing and oil-exporting nations. Second, it implements a symmetric and asymmetric econometric analysis of the reaction of green energy transition to oil price. By doing so, the study will explore potential asymmetries in this relationship, investigating if the repercussions of oil price increases on green energy transition differs from that of oil price decreases. Third, the study utilizes second-generation panel data econometric techniques to investigate the influence of oil prices on green energy transition. More specifically, the analysis is based on cross-section dependence (CSD) tests, cointegration tests which accounts for CSD and the pooled mean group-autoregressive distributed lag (PMG-ARDL) to assess the symmetric and asymmetric repercussions of oil prices on green energy transition. By making the previously discussed contributions, this paper intends to foster a deeper understanding of how oil price and the transition to green energy interact. The outcomes of this research may have noteworthy implications for policymakers, and energy provides and investors seeking to navigate the complexities of energy transition and promote a sustainable energy future.

The rest of this manuscript is structured as follows. Section 2 summarizes the previous literature on the interplay between oil prices and green energy transition. In Section 3, the data and empirical methodology are described, while the results are analyzed on Section 4. Finally, Section 5 presents the concluding remarks and policy recommendations.

2. LITERATURE REVIEW

2.1. Transmission Mechanisms

Prior scholarly works propose various theoretical mechanisms by which oil prices may affect the shift towards green energy. First, the increase in oil prices rise the cost of conventional energy sources, making renewable energy more economically competitive and thus encouraging their adoption (Guo et al., 2021; Özkan, 2023). Contrariwise, a drop in oil price may decrease the attractiveness of clean energy. This channel is known as the Substitution Effect channel. Second, the increase in oil revenues may reduce the interest in investing in clean energy projects in oil-exporting nations, thereby resulting in a inverse association between increased oil price and energy transition (Tambari et al., 2023). This channel is known as the Resource Curse Hypothesis channel. Third, rising oil price volatility can lead to uncertain fossil energy markets and a fall in confidence of investors in those markets (Loang, 2025). This could accelerate the shift towards renewable energy sources, which are known to be less volatile and more stable than conventional energy markets. However, it is worth noting that high uncertainty in energy markets might also deter overall energy investments, even renewables (Avazkhodjaev et al., 2024).

2.2. Empirical Studies

Numerous empirical works have focused on the linkages between oil price and the transition to green energy in different geographical contexts, producing a range of different conclusions. Several studies reported a positive and significant association, indicating that higher oil prices tend to increase green energy transition. For example, Ben-Salha et al. (2022) checked the effects of fossil fuels, including oil, on clean energy use in China. The analysis showed that oil prices increased the demand for clean energy over the long-term, while no significant effects are detected in the short-term. Tambari et al. (2023) analyzed the impacts of oil price on green energy demand across a selection of African countries between 1990 and 2021. The empirical analysis suggested that oil price exerts positively influences clean energy demand in oil-importing nations, as they are considered more economically competitive than oil in those counties. Furthermore, Mukhtarov (2024) explored the impacts of oil price on the use of green energy in China between 1990 and 2020. The empirical analysis highlighted a positive linkage between the variables. Specifically, a 1% upsurge in oil price induced a rise in clean energy demand by 0.16%. On the contrary, Sadorsky (2009) investigated the influence of oil prices on clean energy demand in G7. The author concluded that increases in oil prices negatively affect renewable energy use, i.e., reduces green energy consumption

Other studies found an asymmetric association between oil price and the demand for clean energy. For example, Guo et al. (2021) analyzed the role of crude oil price on clean energy sources in G7 using the nonlinear ARDL model. The outcomes showed heterogeneous impacts of oil prices. Indeed, the positive variations in oil prices are found to have a higher influence on clean energy use than negative variations in the United States, Canada, and Italy, while negative changes dominate in in England and Japan. Furthermore, Sahu et al. (2022) employed the nonlinear ARDL model to analysis the influence of oil prices in the United States. According to the authors, higher oil prices induce increased demand for renewable energy sources, with this effect observed in both the short-run and long-run. Recently, Zabat et al. (2025) examined the implications of oil price fluctuation on clean energy consumption in Saudi Arabia between 1990 and 2020 using the nonlinear ARDL model. The empirical investigation showed an asymmetric connection between the two variables. The authors concluded that upturn in oil price rises the demand for green energy sources. However, a downturn in oil price only the consumption over the short-term.

3. DATA AND EMPIRICAL METHODOLOGY

3.1. Data Description

The aim of this study is to examine the effects of oil price on green energy transition in 10 oil-exporting (Iraq, Qatar, Russia Saudi Arabia, and the United Arab Emirates) and oil-importing countries (China, France, India, Japan and the United States) during the period 2000-2020. Green energy transition is quantified in this paper using the share of renewable energy in total final energy consumption. Moreover, oil price is proxied by real west Texas intermediate (WTI) crude oil price. Alongside oil price, the specification includes a set of control variables that may affect green energy transition. First, we include real gross domestic product as a proxy of economic development. Countries with higher economic growth are those investing in renewable energy and promoting green energy transition. Moreover, total greenhouse gas emissions are introduced in the specification. Indeed, highly polluted countries are those working actively to promote renewable energy projects. Finally, Research and development expenditure is considered as an additional control variable that may affect green energy transition, since countries allowing higher share of income to research and development are those encouraging green innovation technologies. All variables discussed above, except oil price, are obtained from the World Development Indicators dataset provided by the World Bank. Real oil price is collected from the World Bank Commodity Price Data. All variables are taken in natural logarithm to stabilize variance and reduce heteroscedasticity and reduce the impact of outliers. Further details on variables are summarized in Table 1.

Based on the discussion above, the main equation to be estimated may be written as follow:

$$lnGET_{i,t} = \alpha_i + \beta_1\, lnGDP_{i,t} + \beta_2\, lnRD_{i,t} + \beta_3\, lnCO2_{i,t} + \beta_4\, lnOIL_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where green energy transition (lnGET) is the dependent variable, while real GDP (lnGDP), total greenhouse gas emissions ($lnCO_2$), research and development expenditure (lnRD), and oil prices (lnOIL) are the independent variables. α_i denotes the fixed country effect and $\varepsilon_{i,t}$ is the error term.

Table 1: Description of variables

Variable	Acronym	Description	Source
Green energy transition	GET	Renewable energy consumption (% total final energy consumption)	World Development Indicators
Economic activity	GDP	Gross domestic product (constant 2015 US$)	
Total greenhouse gas emissions	CO_2	Total greenhouse gas emissions (Mt CO_2e)	
Research and development	RD	Research and development expenditure (*GDP)	
Oil prices	OIL	West Texas Intermediate (WTI) crude oil price (constant 2010 US$)	World Bank Commodity Price Data

3.2. Empirical Methodology

The empirical investigation involves the estimation of the autoregressive distributed lag (ARDL) model employing the pooled mean group (PMG) estimator introduced by Pesaran and Smith (1995) and Pesaran et al. (1999). The methodology is based on the ARDL(p,q) model which is estimated using the PMG technique. The main equation can express as follows:

$$\Delta\ln(GET)_{it} = \alpha_i + \gamma_{1i}\ln(GET)_{i,t-1} + \gamma_{2i}^{'}X_{i,t-1} + \sum_{j=1}^{p-1}\psi_{1ij}^{*}\Delta\ln(GET)_{it-j} + \sum_{j=0}^{q-1}\psi_{2ij}^{*}\Delta X_{it-j}^{'} + \varepsilon_{1it} \quad (2)$$

Where $i = 1,2\ldots\ldots N$, $t = 1,2\ldots\ldots\ldots T$, N is the number of cross-section units, while T is the number of years. X_{it} is a vector of regressors for cross-section unit i, α_{1i} represents individual fixed effects ε_{1it} refers to error terms. Level terms stand for long-term coefficients, whereas first difference terms represent short-term effects. ε_{it} represents the error term, while Δ is the initial difference operator. The optimal lag orders (p, q) are determined using the SIC or AIC information criteria. The PMG estimator leverages the ARDL methodology in a panel data context, and the inherent link between ARDL and the error correction model means that the PMG estimator is fundamentally based on an error-correcting framework for panel data. The panel ARDL model can be written as an error-corrected model:

$$\Delta ln(GET)_{it} = \mu_i + \varphi_i * ecm_{i,t-1} + \sum_{j=1}^{p-1}\pi_{1ij}^{*}\Delta ln(GET)_{it-j} + \sum_{j=0}^{q-1}\pi_{1ij}^{*}\Delta X_{it-j}^{'} + v_{it} \quad (3)$$

In this equation, π_{1ij}^{*} represents the short-term coefficients, *ecm* is the error correction term, and the term ϕ_i signifies the speed of adjustment towards equilibrium. The adjustment coefficient must be negative to ensure the process adjusts toward the long-term equilibrium. v_{it} represents the error term independently and identically distributed.

According to Shin et al. (2014), modelling the nonlinear relationships involves accounting for the cumulative positive and cumulative negative changes in the explanatory variable (oil price), as shown in Equation 3:

$$\begin{aligned}\Delta ln(GET)_{it} &= \eta_i + \gamma_{1i} ln(GET)_{it-1} + \beta_{1i}^{+}X_{it}^{+} + \beta_{1i}^{-}X_{it}^{-} \\ &+ \sum_{j=1}^{p-1}\Psi^{*}{}_{1ij}\Delta ln(GET)_{it-j} + \sum_{j=0}^{q-1}\delta_{1ij}^{*+}\Delta X_{it-j}^{'+} \\ &+ \sum_{j=0}^{q-1}\delta_{1ij}^{*-}\Delta X_{it-j}^{'-} + \varepsilon_{1it} \quad (4)\end{aligned}$$

Where X_{it}^{+} denote the positive partial sum, designed to detect upward fluctuations in X, while X_{it}^{-} denote the negative partial sum, designed to detect upward fluctuations in X. β_{1i}^{+} and β_{1i}^{-} represent the long-term asymmetric influences of positive and negative fluctuations in oil price on green energy transition, respectively. The coefficients δ_{1ij}^{*+} and δ_{1ij}^{*+} stand for the short-term asymmetric impact of positive and negative fluctuations in oil price on green energy transition, respectively. The positive and negative cumulative changes in the oil price are computed as follows:

$$OIL^{+}_{i,t} = \sum_{j=1}^{t} \Delta OIL^{+}_{i,j} = \sum_{j=1}^{t} \max(\Delta OIL^{+}_{i,j}, 0) \quad (5)$$

$$OIL^{-}_{i,t} = \sum_{j=1}^{t} \Delta OIL^{-}_{i,j} = \sum_{j=1}^{t} \min(\Delta OIL^{-}_{i,j}, 0) \quad (6)$$

Where OIL^{+} and OIL^{-} represent the positive and negative components of oil price, respectively.

4. EMPIRICAL FINDINGS

4.1. Preliminary Analysis

Table 2 summarizes the key descriptive statistics for the full sample and different sub-samples. The table indicates that oil-importing nations have a higher mean renewable energy use (lnGET) compared to oil-exporting nations. This implies that oil-importing nations demonstrate a greater uptake of clean energy sources than their oil-exporting nations. Additionally, the variability in the data for GET is larger among oil-importing nations (between 1.252 and 3.852) than among oil-exporting nations (between −4.605 and 1.313). The table also suggests that oil-exporting nations have a slightly lower GDP compared to oil-importing nations. This is anticipated, given that key oil-importing nations comprise developed countries (France, Japan, US) and high-growth emerging economies (China, India). Furthermore, the descriptive statistics in Table 2 indicate that, on average, oil-importing nations exhibit higher levels of $\ln CO_2$ compared to oil-exporting nations. Indeed, several major GHG emitting nations, such as the United States, China, and India, are classified as oil-importing nations and are included in the sample. Finally, oil-importing countries, characterized by high growth rates, exhibit a considerably higher mean of research and development expenditure compared to oil-exporting nations.

4.2. Cross-Section Dependence Test Results

Prior to examining the variables in the study for unit roots, a cross-section dependence (CSD) analysis was carried out. The aim of this initial step is to guide the selection between first- and second-generation panel unit root tests. The present study employs the CD test provided by Pesaran (2021) for all variables. The outcomes are summarized in Table 3. The results presented in the table suggest rejecting the null hypothesis of no CSD for lnGET, lnGDP, $\ln CO_2$, and lnRD.

Consequently, this implies significant financial, trade, and economic ties exist between the countries in the sample. This situation suggests that a shock originating in one variable of a particular country might be conveyed to other countries. Consequently, the table suggests the presence of CSD for lnGET, lnGDP, and $\ln CO_2$ in the panel dataset, and weaker evidence for lnRD.

4.3. Unit Root Test Results

The use of the panel ARDL methodology does not require that all variables be I(1). It could be used in cases of a mixture between variables I(0) and I(1). However, we cannot use the panel ARDL methodology when some variables are I(2). The presence of unit root for all variables is checked using the CADF panel unit root test suggested by Pesaran (2007). The results are summarized in Table 4.

The CADF panel unit root test was applied to all variables in the study, both at their original values (levels) and after differencing once, employing models that included either a constant term or both a constant and a trend. The results indicate that none of the variables exhibit stationarity at their levels under either

Table 2: Summary of descriptive statistics

Variable	n	Mean	Median	Min	Max
Full sample					
LnGET	210	0.432	1.304	−4.605	3.852
LnGDP	210	27.765	27.920	24.240	30.634
$\ln CO_2$	210	6.903	6.857	4.205	9.606
LnRD	210	0.015	0.178	−3.421	1.243
LnOIL	210	4.075	4.154	3.522	4.573
Oil-exporting countries					
LnGET	105	−1.623	−2.120	−4.605	1.313
LnGDP	105	26.406	26.441	24.240	28.011
$\ln CO_2$	105	5.933	5.594	4.205	7.836
LnRD	105	−0.586	−0.213	−3.421	1.243
LnOIL	105	4.075	4.154	3.522	4.573
Oil-importing countries					
LnGET	105	2.488	2.426	1.252	3.852
lnGDP	105	29.123	29.055	27.409	30.634
$\ln CO_2$	105	7.873	7.951	6.005	9.606
LnRD	105	0.617	0.786	−0.436	1.243
LnOIL	105	4.075	4.154	3.522	4.573

Table 3: CSD test results

Variable	CD test statistics	P-value
lnGET	2.30**	0.020
lnGDP	28.74***	0.000
$\ln CO_2$	3.75***	0.000
lnRD	1.78*	0.070

The asterisks ***, **, and * signify the rejection of the null hypothesis at 1%, 5%, and 10% significance levels

Table 4: CADF panel unit root test

Variable	Levels		First difference	
	With constant	With constant and trend	With constant	With constant and trend
Full sample				
lnGET	−0.68	−1.34	−3.62***	−4.09***
lnGDP	−1.94	−1.94	−2.78***	−3.05**
$\ln CO_2$	−1.74	−1.95	−3.47***	−3.89***
lnRD	−1.62	−2.05	−3.05***	−3.29***
Oil-exporting countries				
lnGET	−0.54	−1.32	−3.86***	−4.22***
lnGDP	−1.31	−1.35	−2.84***	−3.47***
$\ln CO_2$	−1.59	−1.53	−4.42***	−3.42***
lnRD	−2.57	−2.60	−3.05***	−3.14***
Oil-importing countries				
lnGET	−0.87	−2.75*	−3.56***	−3.82***
lnGDP	−1.49	−1.15	−3.47***	−3.84***
$\ln CO_2$	−1.57	−1.67	−2.88***	−3.53***
lnRD	−1.12	−1.05	−3.13***	−3.22***

The asterisks ***, **, and * signify the rejection of the null hypothesis at 1%, 5%, and 10% significance levels specification. However, after applying first differencing to all variables, the null hypothesis was rejected, suggesting they became stationary. Consequently, we can conclude that all variables are I(1). Given that none of the variables are found to be I(2), the panel ARDL approach is a suitable method to employ for further analysis.

4.4. Symmetric Effects of Oil Price on Energy Transition

The objective of this section is to check the influence of oil price and other control variables on the shift towards green energy, considering the entire dataset and its division into oil-exporting and oil-importing nations. The estimation results for the long- and short-run estimates are reported in Table 5. Examining the long-term impacts, the outcomes indicate a positive influence of research and development expenditures on green energy transition across the entire sample and within both country groups. This finding suggest that R&D expenditures play a critical role in advancing green innovation and promoting the shift towards more cleaner energy sources. Additionally, R&D's positive coefficient is larger in oil-importing countries than oil exporters, possibly because the former group predominantly comprises developed and fast-growing emerging economies with a greater focus on R&D investment. Furthermore, the table shows that GDP also contributes to promoting the consumption of green energy sources in all samples. Indeed, more developed countries rely more on green energy sources in order to reduce polluting gases and protect the environment. In addition, CO_2 emissions have significant coefficients in all cases, suggesting that the rise in GHG emissions incentivizes countries to reduce the consumption of brown energy and increase the consumption of green energy in order to mitigate environmental degradation.

Regarding oil price, the PMG-ARDL model indicates coefficients that are both positive and statistically significant across all the countries examined. These outcomes show that a rise in oil price incentivize the full sample of countries to shift towards cleaner energy sources. Specifically, the analysis indicates that a 1% rise in oil price leads to a 1.391% expansion in the proportion of clean energy consumed in the long-run. When considering sub-samples, the analysis indicates that the coefficient associated with oil-exporting nations (1.734) is larger than that of oil-importing nations (1.240). This means that oil-exporting countries in the sample are using the increased revenues from oil to promote green energy use. Oil-importing countries increase the share of renewables due to oil price, since this latter represents additional expenditures for the government. To mitigate the impact of sharp oil price increases, these countries actively pursue to develop renewable energy projects. Examining the short-term dynamics, the bottom section of Table 5 indicates negative coefficients for the error-correction term across the entire sample and within each sub-sample. These results point to the existence of cointegration among oil price (and the included control variables) and the shift towards green energy for all samples. Furthermore, oil-exporting countries exhibit the highest adjustment speed, indicating that their convergence towards the long-run equilibrium occurs more rapidly than in oil-importing countries. With reference to the explanatory variables, the table suggest no significant short-run coefficients for both the control variables and oil price. This suggests that the impacts of explanatory variables, mainly oil price, on green energy transition are characterized by a long-term horizon and necessitate a significant timeframe for their complete manifestation.

4.5. Asymmetric Effects of Oil Price on Energy Transition

This section assesses the asymmetric implications of oil price on green energy transition in the full and various sub-samples. For this purpose, we estimate how rising oil prices (lnOIL_POS) and falling oil prices (lnOIL_NEG) affect GET in both the long-run and the short-run. The estimation results are summarized in Table 6.

First, the long-run estimation suggests that research and development expenditures, GDP and GHG emissions have generally positive and significant coefficients for all countries, which means that these three factors are considered important drivers of green energy transition in all countries. After

Table 5: Long and short-run linear effects of oil price on energy transition

Variable	Coefficients	t-statistics	Variable	Coefficients	t-statistics	Variable	Coefficients	t-statistics
Full sample			Oil-exporting countries			Oil-importing countries		
Long-run effects								
lnRD	0.580***	6.329	lnRD	0.321*	1.914	lnRD	0.637***	13.736
lnGDP	0.182***	15.867	lnGDP	0.263***	2.720	lnGDP	0.145***	14.66
$lnCO_2$	0.858***	5.526	$lnCO_2$	−0.584***	−9.325	$lnCO_2$	1.192***	24.163
lnOIL	1.391***	9.927	lnOIL	1.734***	5.587	lnOIL	1.240***	6.254
Short-run effects								
ECT	−0.556***	−4.888	ECT	−0.815***	−2.831	ECT	−0.485*	−1.922
D (lnRD)	0.345***	2.582	D (lnRD)	0.183	1.150	D (lnRD)	0.443**	2.053
D (lnOIL)	0.090	1.453	D (lnRD[−1])	0.485	1.472	D (lnRD[−1])	−0.053	−0.507
D (lnGDP)	0.480	0.835	D (lnOIL)	0.179	0.670	D (lnOIL)	−0.022	−0.448
D ($lnCO_2$)	−0.629	−1.131	D (lnOIL[−1])	0.194*	1.662	D (lnOIL[−1])	−0.009	−0.293
Constant	13.188***	3.014	D (lnGDP)	−0.327	−0.554	D (LN_GDP)	−0.235	−0.431
Trend	0.026**	2.555	D (lnGDP[−1])	0.243	0.279	D (lnGDP[−1])	−0.749	−4.094
-	-	-	D ($lnCO_2$)	0.607	0.376	D (LN_CO_2)	0.099	0.135
-	-	-	D ($lnCO_2$[−1])	−2.495	−1.443	D ($lnCO_2$[−1])	0.219	0.845
-	-	-	-	-	-	Constant	−6.112*	−1.955

*P<0.10; **P<0.05; ***P<0.01

Table 6: Long and short-run nonlinear effects of oil price on energy transition

Variable	Coefficients	t-statistics	Variable	Coefficients	t-statistics	Variable	Coefficients	t-statistics
Full sample			Oil-exporting countries			Oil-importing countries		
Long-run effects								
lnRD	0.431***	5.712	lnRD	0.289**	1.956	lnRD	0.576***	3.870
lnGDP	1.115***	4.912	lnGDP	−0.424*	−1.754	lnGDP	1.216***	5.615
$\ln CO_2$	1.704***	3.129	lnCO2	1.702***	5.844	$\ln CO_2$	1.774***	4.243
lnOIL_POS	0.403***	5.536	lnOIL_ POS	0.265***	3.193	lnOIL_ POS	0.246***	4.978
lnOIL_NEG	0.052	1.072	lnOIL_ NEG	−0.034	−0.428	lnOIL_ NEG	−0.098	−1.122
Short-run effects								
ECT	−0.206***	−10.411	ECT	−0.358***	−12.780	ECT	−0.311	0.015
D (lnGET[−1])	−0.160	−1.252	D (lnRD)	0.103	1.319	D (lnRD)	0.337	0.247
D (lnRD)	0.072	0.199	D (lnGDP)	0.396	0.757	D (lnGDP)	−0.098	0.908
D (lnRD[−1])	0.517	0.699	D ($\ln CO_2$)	0.578	0.390	D ($\ln CO_2$)	−0.607	0.336
D (lnGDP)	1.073	1.121	D (lnOIL_POS)	0.088	0.295	D (lnOIL_POS)	−0.106	0.322
D (lnGDP[−1])	0.215	0.356	D (lnOIL_NEG)	0.115	0.827	D (lnOIL_NEG)	0.073	0.030
D ($\ln CO_2$)	−3.577***	−5.022	Constant	3.788	1.212			
D ($\ln CO_2[-1]$)	−2.788	−1.389	-	-	-	-	-	-
D (lnOIL_POS)	−0.441	−1.127	-	-	-	-	-	-
D (lnOIL_POS[−1])	−0.205	−0.575	-	-	-	-	-	-
D (lnOIL_NEG)	0.415	1.357	-	-	-	-	-	-
D (lnOIL_NEG[−1])	0.183	0.682	-	-	-	-	-	-
Constant	−11.385	−1.059	-	-	-	-	-	-
Trend	−0.001	−0.087	-	-	-	-	-	-

*P<0.10; **P<0.05; ***P<0.01

disaggregating oil price into its positive and negative partial components, the long-run coefficients of increased oil price are found to be positive and significant according to the PMG-ARDL methodology. Contrarily, the coefficients of oil price decreases are not significant for the full sample and different sub-samples. These outcomes indicate that an upturn in oil prices stimulates a long-term increase in the proportion of renewable energy consumed, but a downturn in oil prices does not significantly influence the shift towards green energy. Specifically, a 1% rise in oil price induces an upsurge in the demand for green energy by 0.403% in the full sample, while a decline has no significant effects. Another important remark from Table 6 is that there are some differences regarding the influence of oil price increases on green energy transition in oil-exporting and oil-importing nations. Specifically, a 1% surge in oil price resulted in a 0.265% acceleration of the green energy transition in oil-exporting nations, and a 0.246% acceleration in oil-importing nations. This indicates a slightly greater responsiveness of the green energy transition to oil price hikes in oil-exporting nations compared to oil-importing ones. Indeed, in periods of high oil prices, oil-exporting nations may use the higher incomes obtained from increased oil price to promote green technologies, invest in infrastructure projects to support sustainable development, promote renewable energy projects diversify their economies away from oil dependence. However, the higher cost of oil for oil-importing countries, driven by rising prices, leads to a greater imperative to transition their energy consumption from fossil fuels, particularly oil, to clean energy. The short-run analysis suggests negative and statistically significant error-correction terms for the full sample and oil-exporting nations, while no significant coefficient is obtained for oil-importing countries. In line with the preceding analysis, the results do not provide robust evidence of a short-run connection between oil price increases and decreases and green energy transition. Furthermore, the control variables exhibit no significant short-term effects, which is consistent with our earlier findings.

5. CONCLUSION AND POLICY RECOMMENDATIONS

The present research aimed to investigate empirically the repercussions of oil price on green energy transition in 10 oil-exporting and oil-importing nations over the period 2000-2020. Empirical analysis employed a set of second-generation panel data techniques that allow accounting for CSD. Particularly, the symmetric and asymmetric influences of oil price on green energy transition are estimated using the PMG-ARDL framework. The specification includes, alongside oil price, three control variables consisting research and development expenditures, income and GHG emissions. The empirical investigation suggests may interesting findings. First, the analysis highlights the existence of CSD for all variables, suggesting the existence of substantial economic interdependencies between the countries included in the sample. Second, the PMG-ARDL methodology suggests the presence of significant positive long-term association between oil price and green energy transition in the full sample, and in oil-exporting and oil-importing nations. However, the positive impacts of oil prices are higher in oil-exporting nations than in oil-importing ones. Moreover, R&D expenditures, GHG emissions and GDP have long-run positive effects on green energy transition. The short-run discussion reported no significant effects of oil prices. Third, the asymmetric analysis revealed that only oil price increases have a positive connection with green energy transition in the long-term. This imply that an upsurge in the oil price increases the consumption of clean energy sources, while a fall have no significant effects. These findings hold for the full sample and the two sub-samples. Finally, a rise in oil price is found to have a higher positive impact on green energy transition in oil-exporting countries than in oil-importing countries over the long-run.

Based on these outcomes, it is possible to formulate policy recommendations to promote environmental sustainability. First, it is important for policymakers in oil-exporting countries to create specific funds to foster the development of the renewable energy sector using oil revenues, particularly during periods of high oil price. Furthermore, those countries should focus their attention on diversifying their economies based on high oil revenues and build a strong renewable energy sector in order to reduce environmental degradation. Second, policymakers in oil-importing nations should emphasize policies and strategies aimed at lessening their vulnerability to fluctuating oil prices and expediting the implementation of economically viable clean energy projects. This could be achieved, for example, by developing and implementing financial subsidies, Feed-in Tariffs, carbon tax and green loans. Third, it is crucial for policymakers across both oil-exporting and oil-importing nations to enhance financial support for R&D in green energy technologies to speed up the energy transition.

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