energies

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The Differential Effects of Oil Prices on the Development of Renewable Energy in Oil-Importing and Oil-Exporting Countries in Africa

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Abstract: The shift to renewable sources of energy has become a critical economic priority in African countries due to energy challenges. However, investors in the development of renewable energy face problems with decision making due to the existence of multiple criteria, such as oil prices and the associated macroeconomic performance. This study aims to analyze the differential effects of international oil prices and other macroeconomic factors on the development of renewable energy in both oil-importing and oil-exporting countries in Africa. The study uses a panel vector error correction model (P-VECM) to analyze data from five net oil exporters (Algeria, Angola, Egypt, Libya and Nigeria) and five net oil importers (Kenya, Ethiopia, Congo, Mozambique and South Africa). The study finds that higher oil prices positively affect the development of renewable energy in oil-importing countries by making renewable energy more economically competitive. Economic growth is also identified as a major driver of the development of renewable energy. While high-interest rates negatively affect the development of renewable energy in oil-importing countries, it has positive effects in oil-exporting countries. Exchange rates play a crucial role in the development of renewable energy in both types of countries with a negative effect in oil-exporting countries and a positive effect in oil-importing countries. The findings of this study suggest that policymakers should take a holistic approach to the development of renewable energy that considers the complex interplay of factors, such as oil prices, economic growth, interest rates, and exchange rates.

Keywords: oil prices; renewable energy; oil-importing and exporting countries

Citation: Tambari, I.J.T.; Failler, P.; Jaffry, S. The Differential Effects of Oil Prices on the Development of Renewable Energy in Oil-Importing and Oil-Exporting Countries in Africa. *Energies* **2023**, *16*, 3803. https://doi.org/10.3390/en16093803

Academic Editor: Donato Morea

Received: 20 February 2023
Revised: 24 April 2023
Accepted: 27 April 2023
Published: 28 April 2023

1. Introduction

Africa faces significant energy challenges, including limited access to electricity and overreliance on traditional and inefficient sources of energy. This situation is particularly acute in rural areas where access to electricity is often non-existent or unreliable. To address these challenges, significant investments in renewable energy technologies are needed. Sources of renewable energy, such as solar, hydro, wind, and geothermal power, have the potential to provide clean and sustainable energy to millions of people in Africa. In response to these challenges, transitioning from non-renewables to renewables has become a critical economic priority [1] Renewable sources of energy, such as wind, solar, wave, and waste, have been identified as viable alternatives to conventional fossil fuels due to their carbon neutrality and inexhaustible nature [2]. Several studies have shown that substituting conventional fossil fuels with renewable energy technologies stimulates economic growth through job creation [3,4]. Thus, significant investments in renewable energy technologies are needed in African countries to mitigate energy challenges.

The macroeconomic effects of oil prices on energy have become a topic of interest, especially following the adverse fiscal impacts of commodity price downturns and the COVID-19 pandemic [5]. In many developing countries, the pandemic has exposed their economic vulnerability due to limited financial resources and dependence on a few key export industries, such as fossil fuels (oil and gas). When oil prices drop, the economies of countries that rely heavily on oil exports may suffer significant losses which can lead to a decline in government revenue, budget deficits, and reduced investment in other sectors, such as renewable energy [6]. This, in turn, can affect the growth of renewable energy industries, as the government may have limited resources to support such initiatives. The COVID-19 pandemic has exacerbated this situation, as it has caused a significant fall in global oil demand, leading to a drop in oil prices. This has had severe implications for many African countries which have limited financial resources to cushion the impact of the downturn [7].

In response, attention has turned towards the macroeconomic effects of oil prices on the growth of renewable energy. Investors and policymakers are seeking to understand how oil prices affect the competitiveness of renewable energy, and how this can be leveraged to support the growth of the renewable energy sector in these countries [8]. For example, higher oil prices may make renewable energy more competitive and attractive as an alternative energy source, and this may provide an opportunity for governments to accelerate their transition to renewable energy [9]. By leveraging these opportunities, African countries may be able to mitigate the negative economic effects of oil price volatility and promote sustainable development through the growth of renewable energy.

The nexus between oil prices and other macroeconomic factors and their effects on renewable energy have been extensively studied in the literature, e.g., [10,11], but there is limited research on the differential effects of oil prices on the development of renewable energy in oil-importing and oil-exporting countries, especially in Africa. In addition, many African countries are among the most exposed countries in the world to the effects of climate change, and the recent setback in progress on access to secure affordable electricity in most African countries where the number of people without access is nearly back to its 2013 peak because of commodity price fluctuations and the COVID-19 pandemic which have destabilized economies and energy systems [12].

Hence, the primary aim of this paper is to consider the sensitive effects of international oil price fluctuations on the development of renewable electricity generation for several African countries pursuing ambitious energy growth and diversification targets in a low-carbon world. To achieve the objective of this research, data from five net oil exporters (Algeria, Angola, Egypt, Libya, and Nigeria) and five net oil importers (Kenya, Ethiopia, Congo, Mozambique, and South Africa) are employed, and a panel vector autoregressive (P-VECM) model is used which makes it possible to take a multifaceted approach to assess the development of the renewable energy response to oil prices and other macroeconomic factors, as the model accounts for the lagged effects of variables.

There are several reasons for selecting these countries. These sets of countries rely heavily economically on natural resources as a key driver of their economies. The first set of countries—Algeria, Angola, Egypt, Libya, and Nigeria—are all net oil exporters, and oil production and exports make up a significant portion of their economies. The second set of countries—Kenya, Ethiopia, Congo, Mozambique, and South Africa—are also known for their natural resources, such as South Africa's mineral wealth and Mozambique's natural gas reserves. These two sets of countries are all actively exploring and investing in renewable energy sources, such as wind, geothermal, solar, and hydroelectric power. The first set of countries—Algeria, Angola, Egypt, Libya, and Nigeria—have traditionally relied on their vast oil and gas reserves to meet their energy needs. However, in recent years, they have also begun to expand their energy mix and invest in renewable energy sources. For example, Egypt has made significant investments in solar energy and has set a goal of generating 20% of its electricity from renewable sources by 2022 [13].

The second set of countries—Kenya, Ethiopia, Congo, Mozambique, and South Africa—have also started to shift towards renewable energy sources to meet their energy needs. For instance, Kenya has made remarkable progress in developing its geothermal energy resources, which now account for around 50% of its total installed capacity [14]. Similarly, South Africa has set a goal of generating 18 GW of renewable energy by 2030 [15]. Overall, both sets of countries are increasingly recognizing the importance of investment in renewable energy sources to cut their dependence on fossil fuels, so as to provide affordable and sustainable energy access to their populations.

This study, therefore, fills a clear gap in understanding the differential effects of oil prices on the development of renewable energy in African countries which are facing energy challenges and economic vulnerability. This study is significant because it provides insights into the various factors that stimulate the development of renewable energy in African countries seeking energy growth and diversification in a low-carbon world. Moreover, this study contributes to the extant literature on the macroeconomic effects of oil prices on renewable energy by examining the differential effects of other macroeconomic variables on the development of renewable energy in net oil-exporting and oil-importing countries in Africa. The study's findings will be of interest to policymakers and investors in African countries seeking to transition to renewable energy sources while ensuring economic growth and sustainability.

2. Literature Review

There are various theoretical frameworks that attempt to describe the relationship between oil prices and the development of renewable energy. One such theory is the "resource curse" hypothesis. The hypothesis is a theory that argues that countries that are rich in non-renewable resources, such as oil, often experience negative economic, social, and environmental consequences [16]. The theory of the resource curse argues that countries that are rich in non-renewable resources become too dependent on the revenue generated by those resources. As a result, they may neglect other important economic sectors, such as renewable energy, and may not invest in diversifying their economy. The resource curse theory also suggests that countries that rely heavily on non-renewable resources are vulnerable to fluctuations in global commodity markets which can lead to economic instability [17,18].

This theory has important relevance for the nexus between oil prices and renewable energy. Countries that are heavily reliant on oil may be less likely to invest in renewable energy even during periods of high oil prices. Additionally, high oil prices may lead to increased revenue for oil-producing countries which can further reinforce their dependence on non-renewable resources [16–18]. Therefore, the resource curse theory highlights the need for countries to diversify their economies and invest in renewable energy to avoid the negative consequences of relying too heavily on non-renewable resources, such as oil.

In the literature, the intricate relationship between oil price and renewable energy development in oil-exporting and oil-exporting countries has not hitherto been well discussed empirically. As shown in Table 1, various studies have been carried out on the relationship between oil prices and renewable energy consumption (e.g., [19–22]). One common finding in these studies is that oil prices have significant impacts on REC. Ref. [19], for example, found a positive nexus between oil prices and renewable energy, while [20,23] found a negative relationship. However, the studies by [21,24–27] suggest that the relationship is not always straightforward and can be both positive and negative. These studies come from different countries and have used different methodologies to investigate the effects of oil prices on REC. The results of these studies are not always consistent, and they reflect the complex and multifaceted nature of the nexus between oil prices and renewable energy.

The literature presented in Table 1 serves as an overview of the research conducted on the nexus between oil prices and renewable energy consumption across different countries and periods. However, despite the large number of studies, there are still some gaps in the literature. For instance, most of the extant studies focus on the impact of oil prices on REC, but hardly any have explored the differential effects of oil prices on the development of renewable energy in oil-importing and oil-exporting countries, especially African countries that depend on fossil fuels and are facing energy insecurity. Therefore, the current study focuses on ten African countries with energy security concerns, separating the net oil-exporters from the net oil importers. These countries were selected from each of the different geopolitical zones in Africa to ensure fair representation.

Table 1. Related literature on oil price and renewable energy development.

Author (s)	Country/Area	Period	Method	Results
Wang et al. (2020) [19]	G-20	1990–2017	Cointegration	Oil price plays a positive role in promoting renewable energy.
Mukhtarov et al. (2020) [20]	Azerbaijan	1992–2015	STSM	A negative nexus exists between oil prices and REC.
Chen et al. (2021) [28]	97 countries	1995–2015	Panel threshold model	Increases in real oil prices lead to increased REC in less democratic countries but there are no significant effects in more democratic countries.
Sahu et al. (2021) [26]	United States	1970–2018	NARDL	Increased oil prices lead to increased renewable energy in both the short and long term.
Murshed and Taha (2021) [25]	4 Asia net oil-importing economies	1990–2018	Cross-sectional dependency	Oil price fluctuations influence movements in REC and in total final energy consumption and aggregate production.
Mukhtarov et al. (2021) [23]	Kazakhstan	1992–2015	FMOLS and CCR	Oil prices have negative effects on REC.
Guo et al. (2021) [24]	G-7 Countries	1980–2018	NARDL	There is positive and negative nexus between oil price and REC (heterogeneity between the countries).
Zhao and Wei (2021) [29]	China	42 sectors in 2015	CGE	Increasing oil prices can advance renewable energy investment.
Lin and Wang (2022) [30]	China		GMM	Oil price uncertainty will increase the market's expectation of renewable enterprises and, thus, stimulate their investment.
Rasheed et al. (2022) [21]	30 European countries	1997–2017	FMOLS and the Driscoll–Kraay regression tests	Rise in oil prices increases the usage of renewable energy.
Royal et al. (2022) [31]	G 7 Countries	1971–2019	FMOLS and DOLS	Oil prices are one of the major drivers of REC in the long run.
Mukhatarov et al. (2022) [11]	Iran	1980–2019	GETS	Oil prices have a significant and negative impact on REC.
Escoffier et al. (2022) [32]	OECD and BRICS	1997–2016	PSTR model	Higher oil prices increase investment in renewable energy.
Husaini and Lean (2022) [33]	8 Asian countries	1980–2017	Panel threshold regression	High oil prices increase public electricity generation.
Zaghdoudi et al. (2023) [34]	China	1970–2019	NARDL	Oil price fluctuations have significant effects on REC.
Kazemzadeh et al. (2023) [35]	49 countries worldwide	1985–2017	Club convergence and PVAR	A granger causal relationship exists between GDP, REC, and oil price.
Deka et al. (2023) [36]	Brazil, China, Indonesia, India, Mexico, Rusia and Turkey	1990–2019	ARDL	GDP, interest rates, and renewable energy promote exchange rate appreciation.
Murshed (2023) [37]	74 developing countries	2000–2018	DCCE-MG	Oil prices hike undermining macroeconomic factors and renewable electrification rate.
Olanipekun et al. (2023) [22]	Global analysis	2004–2019	Wavelet-coherence and quantile regression	Renewable energy use leads to a significant fall in geopolitical oil prices.
Tambari and Failler (2020) [38]	6 African countries	1990–2018	VAR	Oil price has positive impact on investment in renewable energy.
Ali (2022) [39]	South Africa	1990–2019	ARDL and NARDL	Negative shocks in oil prices increase demands for RE.

3. Methodology

3.1. Data Sources

We selected a sample of the top five oil-exporting countries and the top five oil-importing countries, representing the most populous countries with the largest economies from each of the five regions in Africa and the top five leading countries in terms of electricity generation from renewable sources in Africa. These countries include Algeria, Angola, Egypt, Libya, and Nigeria which are the largest oil-producing countries, the largest economies, and among the leading countries in terms of renewable energy generation. We also included net oil-importing countries which are some of the largest economies and leading countries in terms of renewable energy, such as Ethiopia, the Democratic Republic of Congo, Kenya, Mozambique, and South Africa. The study spans the period from 1990 to 2021. The study variables are defined in Table 2.

Table 2. Variable description.

Variable	Variable Description	Unit of Measurement	Expected Sign According to Economic Theory	Source of Data
Renewable energy generation	Renewable energy total generation from hydroelectricity, solar, wind, biomass and waste, hydroelectric pumped storage, non-hydroelectric renewables, geothermal, tides, and waves.	Per capita billions of kilowatt hours.		U.S. Energy Information Administration. http://www.eia.doe.gov/fuelrenewable.html (accessed on 15 March 2023)
Oil prices	The nominal oil price series is the petroleum (Dubai, Brent, Nigerian, and West Texas Intermediate) average crude prices.	The real oil price is calculated from the nominal oil price which is deflated by the inherent consumer price index of the individual countries. USA dollars per barrel.	Positive/negative	The nominal oil price data is taken from the British Petroleum (BP) annual statistical review (1985, 1990, 1996, 2001, 2007, 2012, 2018, and 2022) report and the individual country consumer price index from the International Monetary Fund's International Energy Agency, International Financial Statistics (IFS).
Per capita GDP	The real gross domestic product series is divided by population.	units: per caita US dollars at constant 2015 price; scale: billions.	positive	The United Nations economic database. http://unstats.un.org/unsd/snaama/Introduction.asp (accessed on 15 March 2023)
Interest rate	The real interest is defined as the lending interest rate adjusted for inflation.	Measured as a percentage by the GDP deflator.	negative	World Bank Development Indicator, and the IFS.
Exchange rate	International Monetary Fund exchange rate.	USD exchange rate against national currencies.	negative	The United Nations economic database. http://unstats.un.org/unsd/snaama/Introduction.asp (accessed on 15 March 2023)

3.2. Econometric Model

In this study, the key research questions are addressed by the panel vector autoregressive (P-VECM) framework performed on the basis of the literature. There are several reasons for this choice. The P-VECM model, popularized by [40], is a regression framework that can be used to analyze several dependent variables [41]. The P-VECM framework can show how a given economic variable changes over time and compares changes in the selected data to changes in other variables over the same time period. As a multivariate model, the P-VECM model can be used to evaluate the reciprocal effects of two dependent variables while illustrating how the dynamics in their lags affect other variables and their individual lags [42]. This panel data approach has become increasingly significant in recent years in econometric analysis, particularly for understanding research challenges in energy and macroeconomic data. Moreover, this approach is useful for studying the economic environment of a country and understanding the relations between a system of related variables within an economy or a particular market [43].

In line with the aims of the study and existing literature, such as [44], the model used in this study is as follows:

$$REI = f(Op,\ Gdpc,\ Intr,\ exch) \tag{1}$$

where *REI* represents renewable energy generation per capita, *Op* represents oil prices, *Gdpc* represents real GDP per capita, *Intr* represents real interest rates, and *exch* represents real exchange rates.

The rationale for including *REI*, Oil, *Gdpc*, *Intr,* and exchange rate in Equation (1) is derived from the literature. Refs. [45,46] discovered a considerable nexus between GDP and renewable energy which implies that growth can stimulate renewable energy growth. Thus, a favorable relationship can be expected between GDP per capita and *REI*. The real interest rates represent the financial aspect of the economy, specifically the cost of loan financing, a key factor for investment [47]. When the real interest rate is high, it means that borrowing money is expensive which can discourage investment. The oil price is an alternative to renewable energy, meaning that a higher oil price may lead to greater investment in renewable energy [48]. However, the expectation is negative since an increase in oil price could lead to increased production of non-oil energy [49]. Additionally, the expectation for the exchange rate is negative since fluctuations in exchange rates can affect the cost of financing renewable energy projects, as well as the cost of materials and equipment needed for these projects.

3.3. Econometric Technique: P-VECM Approach

To avoid the problem of endogeneity, which is common when dealing with interdependent variables, in this study, the panel vector autoregressive (P-VECM) approach [50] is adopted. The P-VECM approach allows for the exploration of essential policy issues, such as the ways in which variables can respond to sudden variations in other variables. The application of the P-VECM model involves deducing correlations from the model computations. Each system variable can be interpreted by its lags and the lagged values of the other variables. According to [51], in the P-VECM model, the *G* variables for $t = 1,\ 2,\ \ldots\ldots\ldots,\ T$ and $j = 1,\ \ldots,\ N$ can be concisely given by

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{j=1}^{k-1} \Gamma_j \Delta Y_{t-j} + u_{it} \tag{2}$$

where ΔY_t is a $G \times 1$ vector that includes changes in *REI, Op, Gdpc, intr,* and *exch*. u_{it} represents a vector of dimensions $G \times 1$ of random disturbances with a mean value of zero. Γ_j represents the short-run adjustment, and ΠY_{t-1} represents the error correction term.

In this model, all variables are endogenous. Each equation has one dependent variable, along with others comprising lagged independent variables, resulting in a set of compactly written equations. To assess the potential effects of each variable on REI and the ways in which each variable may influence others, all equations are jointly estimated as a system. The impulse response functions (IRFs) and the variance decompositions (VDs) are, in this study, used to trace the feedback effects from each variable to the others [40].

4. Empirical Analysis

The analysis of the data starts with an examination of the descriptive statistics presented in Table 3. The results show that the average REI is higher in net oil-importing countries, such as Congo, Kenya, and Mozambique, than in net oil exporters, such as Algeria, Libya, and Nigeria. Additionally, the average oil prices are higher and more volatile in net oil importers. Interestingly, the average GDP is also higher for net oil importers. This indicates that there is significant heterogeneity among the net oil exporters and oil importers in terms of REI, oil prices, GDP per capita, interest rate, and exchange rate as evidenced by the variations in means and standard deviations. The wide standard deviations relative to their means suggest that there is high variability in the data series of the variables, and, therefore, a considerable level of heterogeneity. Such heterogeneity is further highlighted in the individual country statistics as depicted in Table 3.

Table 3. Descriptive statistics.

(a) Group Descriptive Statistics (1990–2021)					
	REI	**OP**	**GDPC**	**INTR**	**EXCH**
Net oil-importing countries					
Mean	1.66×10^{-7}	0.635	1585.957	8.827	145.510
Median	1.15×10^{-7}	0.642	575.110	8.369	21.218
Maximum	7.50×10^{-7}	2.660	6259.064	29.583	1989.391
Minimum	3.43×10^{-9}	0.107	203.864	−17.122	2.39×10^{-9}
Std. Dev.	1.91×10^{-7}	0.329	1956.954	12.483	354.583
Net oil-exporting countries					
Mean	8.30×10^{-8}	11,743,685.000	3618.246	−2.828	74.097
Median	5.42×10^{-8}	0.708	3153.474	1.606	39.294
Maximum	3.40×10^{-7}	1.04×10^{9}	13,263.490	38.978	631.442
Minimum	9.24×10^{-10}	0.109	1433.522	−93.513	2.99×10^{-8}
Std. Dev.	7.99×10^{-8}	96,861,240.000	2026.834	22.992	103.631
(b) The Average Values of Each Variable for the 10 Countries (1990–2021)					
	REI	**OP**	**GDPC**	**INTR**	**Exch**
Net oil-importing countries					
Congo	1.21×10^{-7}	0.530	461.678	22.994	603.667
Ethiopia	5.64×10^{-8}	0.629	402.027	−5.735	13.451
Kenya	1.38×10^{-7}	0.777	1306.227	7.956	74.808
Mozambique	4.44×10^{-7}	0.663	406.894	13.809	27.521
South Africa	6.91×10^{-8}	0.575	5352.960	5.111	8.101
Net oil-exporting countries					
Algeria	9.18×10^{-9}	0.582	3579.938	0.747	72.839
Angola	1.35×10^{-7}	51,378,620.000	3172.026	−21.229	105.908
Egypt	1.74×10^{-7}	0.618	3580.606	3.826	6.776
Libya	1.20×10^{-9}	0.453	10,624.700	−1.843	1.069
Nigeria	4.48×10^{-8}	1.379	2008.383	3.138	138.052

Indeed, as reported in Table 3, Angola has an average OP significantly greater than that of the other net oil-exporting countries, such as Algeria and Nigeria. However, this high OP in Angola can be attributed to the country's high rate of price inflation. According to the World Bank, Angola has been experiencing double-digit inflation rates for several years which has led to an increase in the prices of goods and services, including oil prices. As a result, the high OP in Angola can be seen as an indication of the country's high inflation rate, and not necessarily a reflection of its oil production. To prevent the high OP in Angola from affecting the results, we use quantile-based flooring and capping for outliers. In doing this, we apply a floor (i.e., substitution with the 10th percentile) to the lower values and a cap (i.e., substitution with the 90th percentile) to the higher values. By using flooring and capping at the 10th and 90th percentiles, respectively, extreme values in the data are replaced with more representative values, resulting in more accurate analyses [52].

In the empirical analysis, the first step is the application of logarithmic transformation to REI, GDPC, and OP; the INTR and EXCH contain negative values, making them inappropriate for logarithmic transformation. The application of logarithmic transformation to one or more variables results in the enhancement of the model's goodness of fit by converting the distribution of the features to a bell-shaped normal distribution [53]. Non-stationarity is a characteristic of macroeconomic variables that can adversely influence the analysis of econometric time series and panel data since the use of non-stationary data can lead to spurious outcomes. To preclude this issue, a battery of unit-root tests, including the Levin, Lin and Chu (LLC) tests and the Im, Pesaran, and Shin (IPS) tests, were used to determine the stationarity of different series [54,55]. The results of the panel unit root tests are presented in Table 4 for net oil exporters and net oil importers, indicating that the logarithms of REI, OIL, and GDP, along with INTR, are stationary at first difference. Therefore, the first-difference forms of the variables can be utilized in the P-VECM analysis.

Table 4. Panel unit root test (IPS and LLC).

	Net Oil-Importing Countries			
	LLC		**IPS**	
	Level	**First Difference**	**Level**	**First Difference**
log_rei	−1.224 *	−8.766 ***	−1.727 **	−7.480 ***
log_op	−0.628	−3.462 ***	−0.378	−8.079 ***
log_gdpc	−0.654	−8.297 ***	−1.472 *	−9.501 ***
Intr	−4.031 ***	−9.408 ***	−3.522 ***	−8.012 ***
Exch	−0.139	−8.455 ***	−0.940	−9.247 ***
	Net oil-exporting countries			
log_rei	−1.395 *	−3.621 ***	−1.391 *	−8.630 ***
log_op	−0.266	−8.710 ***	−0.284	−6.035 ***
log_gdpc	−0.125	−3.269 ***	−0.806	−8.514 ***
Intr	−3.900 ***	−6.401 ***	−3.990 ***	−7.352 ***
Exch	−0.528	−7.811 ***	−0.672	−9.348 ***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The results presented in Table 4 broadly indicate the stationarity of LOG(REI), LOG(OP), LOG(GDPC), INTR, and EXCH at the first difference for both net oil importers and net oil exporters. These results underscore the importance of conducting panel cointegration analysis as failing to do so can lead to misleading parameter estimates in the economic relationships between variables. Table 5 reports the four 'within-statistics' and three 'between-statistics' obtained using Pedroni's method [56,57]. The results of the panel cointegration analysis suggest that there is a significant cointegration among the time series in both groups of countries. On the basis of this evidence, it can be inferred that co-integrating relationships exist among the study variables within and across the two groups.

Choosing the appropriate number of lags is crucial for P-VECM. As highlighted by [41], including extra lags can lower the likelihood of mis-specification and the resulting bias, but it can also increase standard errors and weaken the test. On the other hand, selecting too few lags may lead to omitted variable bias, as it fails to properly capture the dynamics of the system. Conversely, opting for too many lags can lead to over-parameterization and a loss of degrees of freedom. The results are presented in Table 6. Following standard econometric practice, the optimal lag length is that which decreases the number of moment model selection criteria. Therefore, a first-order P-VECM is the preferred model for net oil-exporting countries on the basis of LR, FPE, AIC, and HQ. For net oil-importing countries, a first-order P-VECM is preferred on the basis of FPE, SC, and HQ.

Table 5. Pedroni panel cointegration test.

		Net Oil-Importing Countries		Net Oil-Exporting Countries	
		Statistic	Weighted Statistic	Statistic	Weighted Statistic
within-dimension	Panel v-Statistic	−1.011	−1.797	−2.150	−2.322
	Panel rho-Statistic	−4.753 ***	−4.528 ***	−2.696 ***	−1.038
	Panel PP-Statistic	−12.784 ***	−10.257 ***	−14.366 ***	−7.271 ***
	Panel ADF-Statistic	−3.192 ***	−3.589 ***	−6.975 ***	−3.588 ***
between-dimension	Group rho-Statistic	−2.740 ***		−0.698	
	Group PP-Statistic	−10.726 ***		−12.288 ***	
	Group ADF-Statistic	−3.429 ***		−4.386 ***	

*** $p < 0.01$.

Table 6. VAR lag order selection criteria.

Net Oil-Exporting Countries						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	−732.110	NA	5.400	26.742	26.872	26.795
1	−722.059	1146.894	2.087 *	14.802 *	15.822 *	15.357 *
2	−695.700	46.921	2.291	15.014	16.447	15.594
3	−674.321	35.916	2.487	15.086	17.171	15.930
Net Oil-Importing Countries						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	−780.766	NA	2.215	29.763	29.879	29.810
1	−773.814	1913.209	0.420 *	13.397	14.093 *	13.679 *
2	−751.822	39.953	0.477	13.447	14.725	13.966
3	−718.858	57.138	0.509	13.314 *	15.173	14.069

* indicates lag order selected by the criterion, LR = sequential modified LR test statistic (each test at 5% level), HQ = Hannan–Quinn information criterion, AIC = Akaike information criterion, FPE = final prediction error, SC = Schwarz information criterion.

As shown in Table 7, the results of the P-VECM analysis suggest that oil price has a positive effect on the development of renewable energy (REI) in oil-importing countries, indicating that as oil prices increase, investment in renewable energy also increases. However, the effect of oil prices on REI in oil-exporting countries is statistically insignificant, indicating that oil-exporting countries are less responsive to changes in oil prices in terms of investment in renewable energy. This finding may be attributable to the fact that the oil-importing countries are more dependent on imported oil and are, thus, more susceptible to price fluctuations. On the other hand, oil-exporting countries may have a vested interest in maintaining the demand for oil, and they may prioritize investments in the oil sector over renewable energy which could explain the insignificant effect of oil prices on REI in these countries. Overall, these results highlight the need for different approaches to the development of renewable energy in oil-importing and oil-exporting countries, taking into account their specific economic conditions and priorities.

The empirical results suggest that real GDP has a significant positive impact on the growth of renewable energy (REI) in both oil-importing and oil-exporting countries, meaning that as real GDP increases, so does the development of renewable energy. This finding shows that economic growth is an important driver for the development of renewable energy in both types of countries. However, the effect of interest rate and exchange rate on REI differs depending on whether the country is an oil importer or an oil exporter. Specifically, the interest rate has a significant negative impact on REI in oil-importing countries, meaning that as interest rates rise, the development of renewable energy decreases. Conversely, the effect of interest rates on REI in oil-exporting countries is significantly negative, indicating that as interest rates rise, the development of renewable energy rises in these countries.

Table 7. P-VECM estimates (dependent variable: REI).

	Net Oil-Importing Countries		Net Oil-Exporting Countries	
	Estimates	**Std. Error**	**Estimates**	**Std. Error**
dlog_rei(−1)	0.181 **	0.081	0.256 ***	0.084
dlog_op (−1)	0.203 *	0.114	−0.058	0.065
dlog_gdpc(−1)	1.393 *	0.710	0.044 *	0.025
d_intr(−1)	−0.057 *	0.004	0.003 *	0.002
d_exch(−1)	−0.015 **	0.007	0.056 ***	0.010
c	0.080 ***	0.032	0.064 **	0.032
ECM	−0.019 ***	0.005	−0.043 ***	0.009
Adjusted R-squared	0.858		0.774	
F-statistic	147.878 ***		172.211 ***	
VEC Residual Serial Correlation LM Tests	69.521 [0.532]		77.098 [0.309]	
VEC Residual Heteroskedasticity Tests	117.290 [0.551]		426.387 [0.226}	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Prob values in [ ].

Similarly, the exchange rate has a significant negative effect on REI in oil exporters, meaning that with an appreciation in the exchange rate, there is a decrease in the development of renewable energy. In contrast, the effect of exchange rates on REI in oil-importing countries is significant and positive, indicating that with an appreciation in the exchange rate, there is an increase in the development of renewable energy. These findings suggest that factors affecting the development of renewable energy differ depending on whether the country is an oil importer or an oil exporter. In particular, factors, such as interest rate and exchange rate, may be more important for the promotion of the expansion of renewable energy in oil-importing countries, while they may have less of an impact in oil-exporting countries. Understanding these differences is important for policymakers seeking to foster the growth of renewable energy in these countries.

Moreover, the coefficient of determination (R-squared) values indicate that the models are a good fit, explaining about 85.8% of the variation in the net oil importers' REI and 77.4% of the variation in the net oil-exporting countries' REI. Additionally, the F-stats are significant, indicating that the overall model is statistically significant. The last two rows show the results of serial correlation LM tests and heteroskedasticity tests. The results indicate that the residuals of the models are non-serially correlated and non-heteroskedastic. This suggests that there are no omitted variables or nonlinearities that might affect the model specification. It is essential that the stability of the VAR model be checked. Figure 1 demonstrates that, for the unit circle, none of the roots are outside which indicates that the P-VECM model is quite stable and that the variables are stationary. Consequently, the estimated model in this study satisfies the model stability test, which means that the interpretation of the estimated IRFs and VRs below is valid [58].

In this study, generalized impulse responses were utilized, in accordance with the innovative studies of Pesaran and Shin [59], to determine the impacts of shocks to independent variables on REI as well as how long these effects last. Figure 2 illustrates the IRFs of REI to the variables for a 10-year period. The results show that unexpected shocks to oil prices lead to a significant rise in REI for net oil exporters throughout the 10-year period but not in oil-importing countries. Moreover, unanticipated shocks to real GDP per capita led to a positive trend in REI for both net oil exporters and oil importers over the 10-year period.

On the other hand, unanticipated shocks to interest rates (INTR) led to a negative trend in net oil importers, but the effect is the reverse in net oil exporters over the same period. Similarly, unanticipated shocks to the exchange rate (EXCH) led to a negative trend in net oil importers but a positive trend in net oil exporters over the 10-year period. It is worth noting that these findings are in line with the results obtained via the P-VECM results.

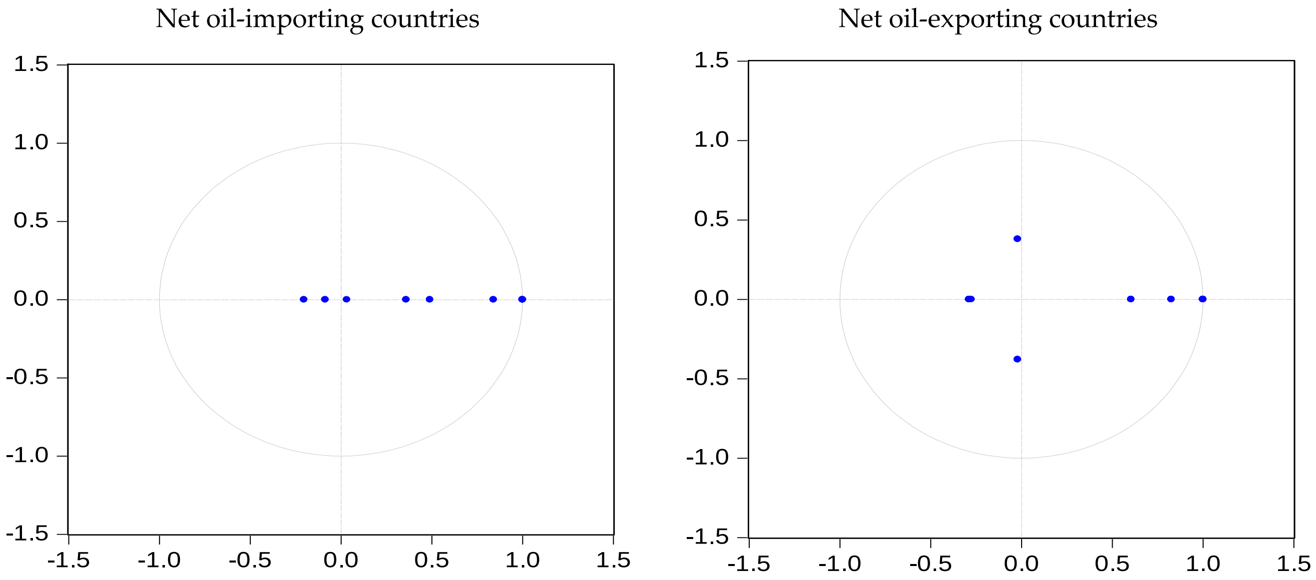

Figure 1. Roots of characteristic polynomial.

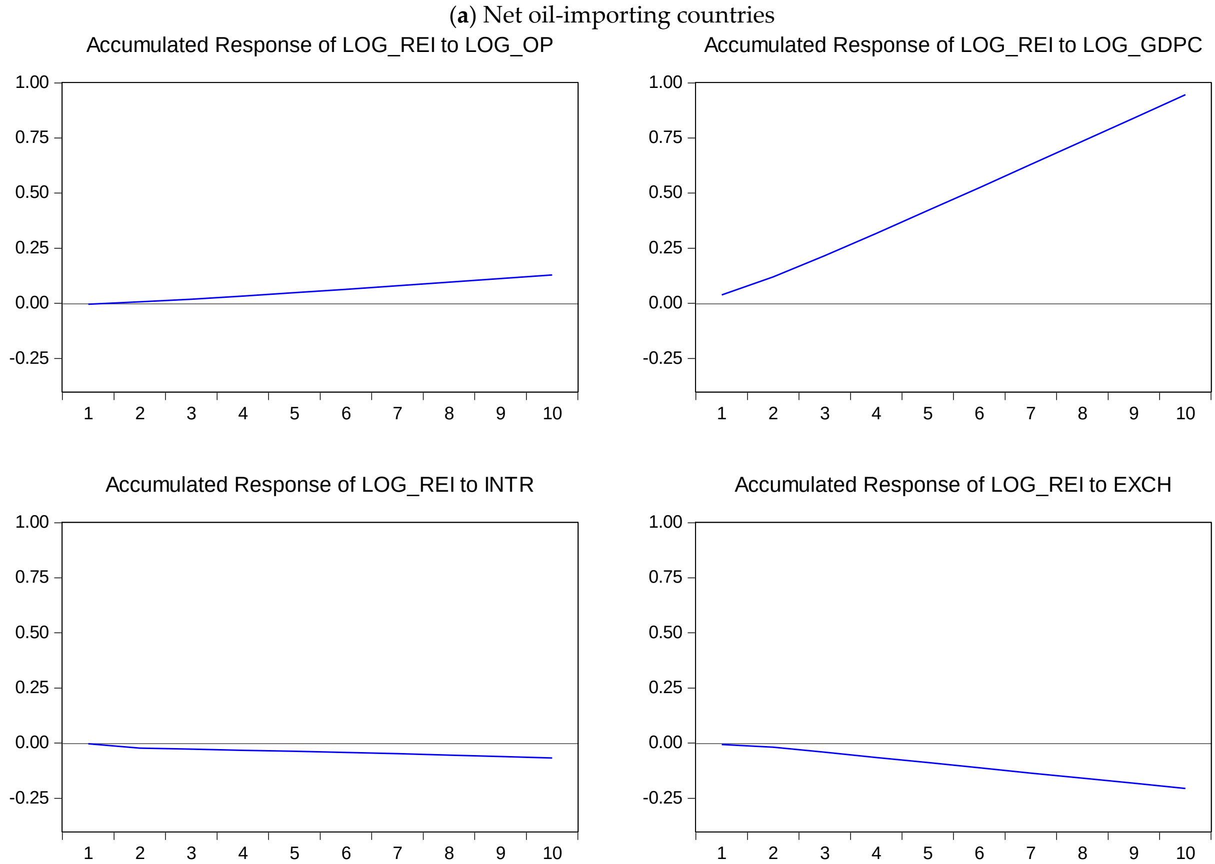

Figure 2. *Cont.*

(**b**) net oil-exporting countries.

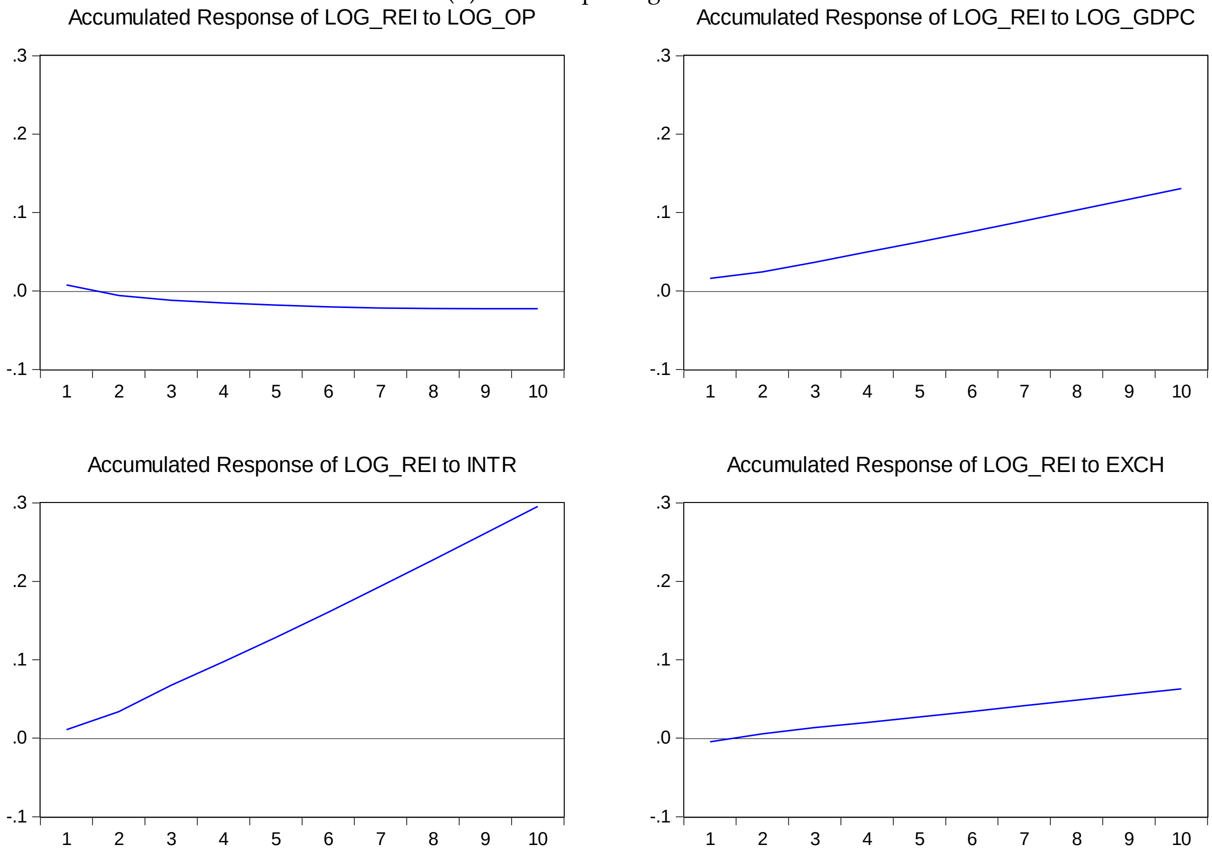

Figure 2. Generalized impulse responses.

The empirical results of the VRs for REI are presented in Table 8. The analysis indicates that oil prices account for a larger proportion of the future variations in REI for net oil importers compared to oil exporters. In the first year, the contribution of oil price to variations in REI is zero, but this increases to 0.381% and 0.096% after 20 years for net oil-importing and oil-exporting countries, respectively. This suggests that oil price is a more significant factor influencing REI in net oil importers than in oil exporters. It is important to note that these interactions are in line with the findings obtained via the P-VECM results.

Table 8. Variance decomposition analysis.

(a) Net Oil-Importing Countries						
Period	**S.E.**	**LOG_REI**	**LOG_OP**	**LOG_GDPC**	**INTR**	**EXCH**
1	0.349	100.000	0.000	0.000	0.000	0.000
5	0.699	96.352	0.219	3.148	0.064	0.217
10	0.979	95.186	0.309	4.193	0.038	0.275
15	1.195	94.746	0.354	4.576	0.032	0.293
20	1.378	94.512	0.381	4.775	0.030	0.303
(b) Net Oil-Exporting Countries						
Period	**S.E.**	**LOG_REI**	**LOG_OP**	**LOG_GDPC**	**INTR**	**EXCH**
1	0.305	100.000	0.000	0.000	0.000	0.000
5	0.568	98.984	0.211	0.006	0.703	0.096
10	0.785	98.796	0.150	0.009	0.937	0.108
15	0.954	98.698	0.116	0.010	1.061	0.114
20	1.098	98.637	0.096	0.011	1.138	0.118

Cholesky Ordering: LOG_REI LOG_OP LOG_GDPC INTR EXCH.

Robustness Checks

To ensure the robustness of the analysis, in this study, two-step system GMM estimates were utilized in addition to the P-VECM analysis. The use of system GMM estimators in panel data analysis is preferred for four key reasons. Firstly, ordinary least squares and within-group estimators are known to result in biased estimates in dynamic panel regressions, whereas the system GMM estimator eliminates this bias. Secondly, the system GMM estimator provides efficient estimates even in the presence of autocorrelation, heteroscedasticity, and correlations between the regressors and past and current values of the error. Thirdly, the system GMM estimator takes care of the problems of endogeneity, fixed effects, and dynamic panel bias. Fourthly, the system GMM estimator is considered more efficient than the difference GMM estimator proposed by [60]. Two variants of the system GMM estimator are the one-step and two-step GMM estimators. However, efficient one-step GMM estimators are rare. In contrast, two-step GMM estimators produce a lower asymptotic variance, making it preferable to one-step GMM estimators [61,62].

Similar to the previous analysis, the empirical results of the two-step system GMM presented in Table 9 indicate a significant positive nexus between oil prices and REI in the net oil importers, while it is non-significant for net oil-exporting countries. Furthermore, real GDP has a significant positive impact on REI in both net oil-importing and net oil-exporting countries. The interest rate has a significant effect on REI in oil importers only, and the exchange rate has a significant effect on REI in both net oil importers and net oil exporters. It is noteworthy that the estimates reported in Table 9 are in alignment with the P-VECM findings discussed earlier. The lower part of Table 9 presents the most crucial diagnostics of the GMM results, which indicate that the GMM estimates are robust. Specifically, the errors of the models are serially uncorrelated, since there is no second-order autocorrelation (of the differenced residuals), although there is residual autocorrelation with an order of one in some cases. Additionally, the Hansen test indicates the validation of the over-identifying restrictions, further supporting the findings of the study.

Table 9. Two-step system GMM estimates (dependent variable: REI).

	Net Oil-Importing Countries	**Net Oil-Exporting Countries**
Log-rei	0.395 *** (0.018)	0.482 *** (0.012)
Log_op	0.015 *** (0.004)	0.018 (0.014)
Log_gdpc	0.058 ** (0.027)	0.079 ** (0.038)
Intr	−0.023 * (0.012)	0.003 (0.002)
Exch	−0.059 *** (0.018)	0.092 *** (0.027)
C	−0.261 *** (0.015)	0.182 *** (0.017)
Arellano–Bond test for AR(1)	−1.664 [0.095]	−1.116 [0.262]
Arellano–Bond test for AR(2)	−0.565 [0.573]	−0.482 [0.631]
Hansen J-test	27.793 [0.248]	30.187 [0.159]

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in ( ). p-values in [ ].

To achieve greater robustness, individual country VAR estimates were computed. The individual country VAR estimates reported in Table 10 are consistent with the P-VECM findings above. The results, as before, demonstrate that oil price has a statistically significant positive effect on REI for all five oil importers. However, the impact of oil prices on REI in oil exporters is statistically insignificant, except for Algeria, where the average oil price is significantly greater than that of other net oil-exporting countries, such as Algeria and Nigeria. The positive significance of OP for Angola can be attributed to the country's high rate of price inflation. The higher oil prices positively affect REI in Angola, making renewable energy more economically competitive.

Table 10. Individual country VECM estimates (dependent variable: REI).

			Net Oil-Importing Countries		
	Congo	**Ethiopia**	**Kenya**	**Mozambique**	**South Africa**
dlog_rei(−1)	0.511 ***	0.245 ***	0.190 ***	0.428 ***	0.382 ***
dlog_op(−1)	0.092 **	0.082 **	0.038 *	0.087 **	0.093 **
dlog_gdpc(−1)	0.088 **	0.079 **	0.012 *	0.019 *	0.065 **
d_intr(−1)	−0.043	−0.074 **	−0.045 *	0.004	−0.021 *
d_exch(−1)	−0.013 *	−0.068 **	−0.077 **	−0.053 ***	−0.064 **
c	−0.418 ***	−0.396 *	0.878 ***	0.739 **	0.277 *
Ecm	−0.081 ***	−0.029 ***	−0.007 *	−0.036 **	−0.096 ***
Adjusted R-squared	0.836	0.763	0.962	0.868	0.794
F-statistic	142.995 ***	256.793 ***	377.808 ***	175.973 ***	278.161 ***
			Net Oil-Exporting Countries		
	Algeria	**Angola**	**Egypt**	**Libya**	**Nigeria**
dlog_rei(−1)	0.855 ***	0.130 ***	0.224 ***	0.212 ***	0.663 ***
dlog_op(−1)	−0.032	0.076 ***	−0.070	−0.056	−0.025
dlog_gdpc(−1)	0.039 *	0.044 *	0.006 *	0.029 *	0.058 *
d_intr(−1)	0.004	0.013 *	0.008 *	0.016 *	0.024 *
d_exch(−1)	0.055 **	−0.021 *	0.033 *	0.072 ***	0.049 *
c	0.965 ***	0.769 **	0.972 ***	0.650 **	0.704 **
Ecm	−0.078 ***	−0.047 **	−0.059 ***	−0.038 *	−0.024 *
Adjusted R-squared	0.764	0.922	0.735	0.863	0.895
F-statistic	278.161 ***	108.548 ***	176.044 ***	324.915 ***	385.711 ***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In addition, real GDP per capita has significant positive effects on the growth of renewable energy (REI) in all of the countries, meaning that as real GDP per capita increases, so does the expansion of renewable energy. The interest rate, however, has significant negative effects on REI in the oil-importing countries, except in Congo and Mozambique where interest rates are quite high. The insignificance of the relationship between interest rates and REI in Congo and Mozambique can be explained by the fact that high-interest rates increase the cost of borrowing, making it more expensive for firms to finance renewable energy projects in these countries. On the other hand, the effect of interest rates on REI in the oil-exporting countries is significantly positive, indicating that as interest rates rise, the development of renewable energy rises in these countries. Furthermore, the exchange rate has a significant negative effect on REI in oil-exporting countries, meaning that with the appreciation of the exchange rate, the development of renewable energy decreases. In contrast, the effect of exchange rates on REI in oil-importing countries is significant and positive, except for Angola where the exchange rate is negative, indicating that the depreciation in the exchange rate in that country is negatively affecting the growth of renewable energy. The impulse responses and variance decompositions of the individual country VAR estimates are also in line with the findings from the P-VECM model (these data are not presented here to save space, but they are available on request). As before, these findings suggest that the factors affecting the growth of renewable energy differ depending on whether the country is an oil importer or an oil exporter.

5. Discussion and Implications

The positive impact of oil prices on REI in oil-importing countries can be explained well by the fact that higher oil prices increase the cost of fossil fuels and make renewable energy more economically competitive. This finding is in accord with the findings of extant studies showing a positive relationship between oil prices and the development of renewable energy e.g., [19,32,38]. In oil-importing countries, where the cost of fossil fuels can be a significant burden on the economy, higher oil prices can make renewable energy sources more competitive, driving investments in clean energy technologies. This effect can be seen in countries, such as Egypt, Ethiopia, Kenya, and South Africa, which have made significant investments in renewable energy despite having little or no domestic oil reserves [63].

In contrast, the insignificant effects of oil prices on REI in oil exporters may be attributable to the fact that the countries rely heavily on oil exports for their economic growth, and, thus, have less incentive to invest in alternative sources of energy. This finding accords with the "resource curse" hypothesis which suggests that countries with abundant natural resources may have less diversified economies and be less willing to invest in alternative sources of energy [64].

The positive nexus between the real GDP per capita and REI found in this study for both oil importers and oil exporters is in line with extant research identifying economic growth as a key driver of renewable energy development [65,66]. This relationship can also be explained by the fact that economic growth leads to an increase in demand for energy which, in turn, creates opportunities for investment in renewable energy sources [66]. Additionally, economic growth can lead to improvements in technology and infrastructure, making renewable energy development more feasible and cost effective [66,67]. The significance of this relationship in both oil importers and oil exporters suggests that economic growth is a universal factor driving renewable energy development, regardless of a country's status as a net importer or exporter of oil.

The significant negative relationship between interest rates and REI in oil-importing countries can be explained by the fact that high-interest rates increase the cost of borrowing, making it more expensive for firms to finance renewable energy projects. This finding is in accord with the result of extant studies, in which a negative relationship was found between interest rates and investment in renewable energy in developing countries [68,69]. Conversely, the significant negative nexus between interest rates and REI in oil-exporting countries could be due to the fact that these countries typically have large oil revenues which may make them less reliant on borrowing to finance renewable energy projects. Furthermore, the availability of cheap and abundant fossil fuels may reduce the incentive for firms to invest in renewable energy even when interest rates are low [70].

The empirical results suggest that the exchange rate plays a crucial role in shaping the investment behavior in renewable energy in oil exporters and oil importers. The negative effect of exchange rates on REI in oil-exporting countries could be due to the fact that as exchange rates appreciate, the price of oil increases, leading to a drop in the demand for alternative energy sources, such as renewables [71]. On the other hand, the positive effect of exchange rates on REI in oil importers could be a result of the fact that with appreciating exchange rates, the cost of importing oil decreases, making investment in renewables more competitive and attractive [36].

6. Concluding Remarks

The differential effects of international oil prices and macroeconomic factors on the development of renewable energy in Africa were analyzed in this study while also considering the different statuses of net oil importers and net oil exporters. For instance, the results indicate that higher oil prices positively affect REI in oil-importing countries, making renewable energy more economically competitive. Economic growth is also a significant driver of REI. While high-interest rates negatively affect REI in oil-importing countries, the effect is positive for oil-exporting countries. Exchange rates play a crucial role in the expansion of renewable energy, with negative effects on REI in oil-importing countries but positive effects in oil-exporting countries.

6.1. Contributions

This study makes a significant contribution to our understanding of the factors influencing the development of renewable energy in Africa. The identification of key macroeconomic factors, such as international oil price fluctuations, economic growth, interest rates, and exchange rates, is an important step in developing effective policies to support the growth of renewable energy. By understanding the nexus between these factors and the development of renewable energy, policymakers can develop targeted interventions that support the expansion of renewable energy infrastructure.

Furthermore, this study highlights the importance of considering the status of countries as net oil-importers or net oil-exporters in the investigation of the nexus between macroeconomic factors and renewable energy. This distinction is important because the impact of macroeconomic factors on the development of renewable energy can differ depending on a country's status. For example, higher oil prices have a positive impact on the development of renewable energy in net oil-importing countries, but they may have an insignificant effect in net oil-exporting countries. Understanding these differences is critical to developing effective policies that support sustainable energy transitions, especially in African countries.

6.2. Policy Recommendations

Based on the above findings of this study, the following policy implications are suggested:

- Encouragement of investment in renewable energy: Policymakers in oil-importing countries should encourage the development of renewable energy by offering financial incentives, such as tax breaks, subsidies, or low-interest loans, to potential investors. This will help to make renewable energy more economically competitive, particularly when oil prices are high.
- Promotion of economic growth: Policymakers should implement policies that promote economic growth, such as infrastructure development and job creation, which will drive the growth of renewable energy. This can be achieved through public–private partnerships or government-led initiatives.
- Reduction of interest rates: Policymakers should reduce interest rates to encourage investment in renewable energy in net oil-importing countries. High-interest rates may discourage investors from pursuing renewable energy projects, particularly in the early stages, when returns on investment may be uncertain.
- Management of exchange rates: Policymakers should manage exchange rates carefully to promote the development of renewable energy in the oil-importing countries. This can be conducted through measures, such as currency stabilization funds, which can help to reduce volatility and make investment in renewable energy more predictable.
- Support of technology transfer: Policymakers should facilitate the transfer of renewable energy technology to net oil-importing countries to help them overcome technological barriers to the development of renewable energy. This can be conducted through partnerships with technology providers or through capacity-building programs.

Overall, policymakers should aim to create a conducive environment for the growth of renewable energy by considering the complex interplay of factors (e.g., such as oil prices, economic growth, interest rates, and exchange rates) that affect it. By doing so, they can help their countries transition towards a more sustainable energy future and reduce their dependence on fossil fuels.

6.3. Limitations and Future Research Directions

Despite the relevant findings of this study, there are some limitations that need to be considered. First, the study only focused on the impact of a limited number of variables on renewable energy development in a sample of countries, due to data availability. Other factors that may affect renewable energy development, such as government policies, technological advancements, and social attitudes towards renewable energy, were not considered. Therefore, future research should take into account a wider range of variables to provide a more comprehensive understanding of the factors that drive renewable energy development, particularly in the context of developing countries, such as those in Africa.

In addition, future research may explore the effects of policy interventions on renewable energy investment in African countries. For example, further investigation is needed on the effectiveness of government incentives, such as tax breaks and subsidies, for promoting renewable energy development. Research could also examine the relevance of public–private partnerships in increasing investment in renewable energy and whether such partnerships can effectively leverage private sector resources to support sustainable energy initiatives in African countries. This stream of studies should aim to include variables that measure financial resources available to support investments in renewable energy.

Another important direction for future research is to explore the potential for regional collaboration to support the development of renewable energy. For instance, African countries could collaborate to develop joint renewable energy projects or share knowledge and expertise in the development of the renewable energy infrastructure. Research could investigate the potential benefits and challenges of such collaborations, as well as identify effective strategies for facilitating cross-border cooperation on renewable energy initiatives. In addition, future research could explore the potential for international support, such as funding from international organizations or partnerships with foreign companies, to support renewable energy investment in African countries.

Author Contributions: Conceptualization, I.J.T.T.; Methodology, I.J.T.T. and S.J.; Software, I.J.T.T.; Validation, I.J.T.T.; Formal analysis, I.J.T.T.; Resources, I.J.T.T. and P.F.; Data curation, I.J.T.T.; Writing—original draft, I.J.T.T.; Writing—review and editing, I.J.T.T., P.F. and S.J.; Supervision, P.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data will be made available on request.

Conflicts of Interest: The authors declare that they have no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

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