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ECONOMIC POLICY UNCERTAINTY AND RENEWABLE ENERGY CONSUMPTION: EVIDENCE FROM OIL-RICH COUNTRIES

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Abstract: Global renewable energy consumption continues to decline in real terms and threatens our capacity to achieve energy security and climate change objectives. This study aims to shed light on the influence of uncertainty in economic policies, financial globalisation, oil prices, and income on a shift in renewable energy use. The study focuses on the OPEC member countries where renewable energy sources are declining. The study makes use of a data set of 11 economies between 2000M01 and 2020M12 and employs a range of heterogeneous approaches to analyse the effects. The cross-sectional dependence and slope homogeneity tests demonstrate that slope heterogeneity occurs across nations and that there exists a correlation between the cross-sectional units. The Westerlund co-integration results show that economic policy uncertainty, financial globalisation, oil price, income, and renewable energy have stable and long-run relationships. We reached the following conclusions based on the dynamic common correlated estimation results: First, financial globalisation increases renewable energy usage. Second, income appears to be insignificant. Third, both the economic policy uncertainty and the oil price variables have shown negative effects towards renewable energy use. This implies that these nations have not leveraged their growing affluence to shift away from traditional energy sources and towards green energy resources. It is therefore crucial for these nations to advance their finances through globalisation to promote the transition to a low-carbon economy.

Keywords: Renewable energy, oil prices, economic policy uncertainty, financial globalisation.
JEL Codes: F64, F65, Q5, Q2, E31, C32.

Introduction

Global renewable energy consumption continues to decline in real terms and threatens our capacity to achieve energy security and climate change objectives (International Energy Agency, 2018). While there exists some empirical evidence about the drivers of renewable energy supply (Bloch *et al.,* 2015), insufficient renewable energy investment by the private sector and other relevant authorities is "a clear indication" that we are still yet to fully understand the drivers of renewable energy consumption (Masinia & Menichetti, 2013). Certainly, the global integration of financial systems and uncertainty in government policies regarding the economy can greatly impact renewable energy in both negative and positive ways. Additionally, we need more global financial integration and economic strategies to advance technology and create new inventions that will produce more clean energy. However, the increasing use of renewable energy and global connections raises significant worries about how effectively we use energy and how helpful it is. The shortage of renewable energy sources is making it take longer for renewable energy use to grow as much as we had hoped. Because of this, experts in energy and government officials are working on finding ways to generate more renewable energy sources so that we can use them for a long time. In addition, renewable energy can greatly fulfil our energy requirements while reducing the amount of CO_2 released into the atmosphere. The world economy is showing a big interest in making more clean energy and highlighting the importance of using clean energy. It is vital to develop energy technologies that produce energy efficiently and are eco-friendly to protect against potential environmental changes and ensure the continuance of nature's survival. Therefore, countries must update their energy infrastructure to incorporate more renewable sources of energy, necessitating the exploration of novel techniques to harness energy from natural resources, such as the sun and wind. This will enable the promotion of renewable energy usage while gradually decreasing dependency on traditional energy sources.

Renewable energy should be focused on as a sustainable alternative to regular energy because it can satisfy the growing need for energy. Globalisation has made it easier for people to access new technologies. This has helped increase the use of renewable energy (Koengkan *et al.,* 2020). In the energy sector, globalisation also helps more money to be put into projects and makes it easier to switch to new technology. Similarly, to this, the authors Padhan *et al.* (2020), say that we need better technology to make more renewable energy. Globalisation can greatly increase the use of clean energy by improving technology in green energy. Globalisation means that countries can share and use new technologies. This helps all countries because it encourages more use of renewable energy.

The essential issues that have captivated the intrigued of analysts after the realisation of budgetary liberalisation by most growing nations are budgetary integration and the co-movement of the capital streams. The extant researchers built up that financial globalisation coordinates and promotes local financial markets into the global financial framework and thus gets more delicate to global financial stuns (Wang & Ye, 2016; Asongu *et al.,* 2017). Additionally, with the visit event of financial crises, which increments changes within the developing markets, the money-related investigation has moved its centre on the investigation of co-movement volatility of different capital streams over the world. Successful economic development and stability often require the participation of both mainland and territorial budgets. This can foster greater financial integration within global economic systems, leading to improved financial division growth and stability.

As such, the expansion and spread of renewable energy depend a lot on global financial cooperation and spending. Financial investments are closely linked to the transfer of technology from the countries where inventions are made to the countries where these inventions are used. However, producing renewable energy attracts higher resources at the beginning compared to traditional energy sources because renewable energy projects need higher initial investments. Having more money means banks and investors have more options for investing and making money. This can help the banks and the stock markets to grow and develop. Global financial integration can greatly benefit efforts to promote renewable energy by reducing the costs associated with securing funding. According to Ibrahim and Hanafy (2020), financial globalisation increases international capital flow, which benefits countries' well-being.

It is important to note that uncertainty within the global budgetary framework persists as long as financial capital flows across the globe remain coordinated. This factor causes alarm among economies around the world and leads to scepticism as budgetary segments of different countries come largely into play to achieve the required advancement. As such, whereas a few economies find these vulnerabilities within the money-related segment as a challenge that pulls back their development in the financial system, a few are making use of the challenges and progressing their budgetary framework by the transformation of locally gathered assets into loaning for country's investors (Asongu *et al.,* 2017).

The growth of finance is affected a lot when the economy's policies are uncertain. However, uncertainty in economic policy is expected to affect the economy negatively. High levels of uncertainty about economic policy will not only slow down economic activity but also decrease financial sector activities and delay new funding projects. Economic policy uncertainty is causing changes in how the government and politics work. This will also affect things like how businesses get funds, their chances of making good investments, and the amount of profit they make. Since the effects of economic policies cannot be sure, changes are needed to all economic operations. Moreover, it is impossible to predict economic matters, especially when, how accurately, and if countries will be able to deal with uncertainties in energy production and policies. The economy grows a lot when there is a lot of energy and good policies. Nevertheless, if the economic policies are unsure, things can change and affect the growth of the economy. It is important to study renewable energy because it is expected to be linked positively with the upcoming energy policy approach. The growth of renewable energy demand is being held back because of uncertainties in economic policies. However, these uncertainties can also encourage the growth of renewable energy demand. Ko and Lee (2015). Christou *et al.* (2017) found that when there is uncertainty in economic policies, it leads to a decrease in investment, especially in financial assets.

Financial globalisation is when finances and investments move freely across border countries. This helps to share new green technology and ideas, which can improve a country's ability to create clean energy and use energy more efficiently. This can greatly reduce the cost of energy and also increase the number of people using renewable energy, which helps create a sustainable environment for the future. Financial globalisation is when the financial industry and services grow globally, bringing more funds from other countries into one's own. This will not only guarantee that you have enough funds and savings for the future, but it will also help produce more renewable energy. Global financial integration helps improve energy efficiency and economic growth by facilitating the exchange of technology and financial resources. This leads to greater economic expansion through the strengthening of energy systems, technology, and financial sectors. In order to facilitate sustainable economic growth, we must formulate and implement robust economic policies that promote renewable energy utilisation and enable individuals to achieve greater financial stability. We believe that consistent and positive economic policies are essential for the overall development of a nation, as opposed to policies that introduce uncertainty and volatility. All countries in the world need to use clean energy, as stated in SDG-7.

It is predicted that the OPEC member countries might produce more clean energy because of their increased financial integration, higher oil prices, more income, and their respective economic policies. They may use modern green technologies or other methods to do that. In this study, we examine the effects of economic policy uncertainty, oil prices, income and financial globalisation in 11 OPEC member countries on renewable energy consumption. It is important to note that we sampled these countries based on the fact that they heavily depend on fossil fuels for their energy needs. The study covers the period from January 2000 to December 2020. In addition, no research to the best of our knowledge has looked into the influence of financial globalisation, oil prices, income and economic policy uncertainty on renewable energy consumption in the sampled countries. This is an important issue because these determinants are essential for increasing the production of renewable energy. To make renewable energy better and more effective, we need assistance from financial globalisation and stable economic rules. Our research focused on 11 OPEC member countries that have been experiencing a decline in renewable energy consumption. The objective is to explore the relationship between economic policy uncertainty, oil prices, income, financial globalisation, and renewable energy in these countries. This is because the carefully selected determinants are crucial in understanding how renewable energy changes over time. This is also a very important issue to consider because sometimes renewable energy production may decrease because of uncertainty in economic policies and constraints related to global financial integration. It is helpful to understand how EPU and FG affect the amount of renewable energy produced and used in the 11 OPEC member countries (Algeria, Angola, Congo, Kuwait, Gabon, Iraq, Libya, Nigeria, Saudi Arabia, the United Arab Emirates, and Venezuela). We use different statistical techniques to understand how different OPEC member nations affect each other. We are particularly influenced by the methods developed by Pesaran (2004). The Cross-Sectional Augmented Im-Pesaran-Shin (CIPS) and CADF panel unit tests are used to analyse the stationarities of variables. The research also used a Westerlund co-integration for the long-run relationship test. We also used the dynamic common correlated effects for data estimation. Although the study uses heterogeneous techniques because of their importance in the analysis, we also had to conduct all the necessary preliminary tests to establish reasonable evidence that the use of heterogeneous techniques is required.

The results make a valuable contribution to the teaming body of literature and our growing understanding of the drivers of renewable energy consumption and are particularly relevant for policymaking aimed at reducing greenhouse gas emissions, achieving energy supply security, decarbonising the value chain, and transitioning to a low-carbon economy. Despite the contributions provided by this study, the study is subjected to some potential limitations. As the primary aim of this research is to examine the effects of financial globalisation, economic policy uncertainty, oil price and income on renewable energy consumption in 11 OPEC member countries, some countries in the list due to the lack of availability of data for the nations, they were not included in this study.

Literature Review

Economic Policy Uncertainty and Renewable Energy Consumption Nexus

Economic policy uncertainty can affect renewable energy consumption. This can be good for renewable energy or bad for it. Wei *et al.* (2021) looked at how uncertainty in economic policies affects the production of energy in China. They examined data from 1995 to 2019. They found that when there are uncertainties in economic policies, people tend to increase their demand for renewable energy. Similarly, Chu and Le (2022) studied how uncertainty about economic policies affects the use of renewable energy in the G7 countries. Their research shows that when people are uncertain about economic policy, their demand for renewable energy increases. In comparison, Liu *et al.* (2020)

Table 1: A summary table of abbreviations used in this article

OPEC	Organisation of the Petroleum Exporting Countries	**EPU**	Energy policy uncertainty
CO2	Carbon dioxide	**CADF**	Cross-Sectional Augmented Im-Pesaran-Shin
FG	Financial globalisation	**ARDL**	Auto-regressive distributive lag
FD	Financial development	**OECD**	Organisation for Economic Cooperation and Development
SDG	Sustainable development goals	**REC**	Renewable energy consumption
GMM	Generalised method of moment	**GDP**	Gross domestic product
FMOLS	Fully modified least square	**DOLS**	Dynamic ordinary least square
EPUI	Economic Policy Uncertainty Index	**CD**	Cross-sectional dependency
CIPS	Cross-Sectional Im-Pesaran-Shin	**DCCE**	Dynamic common correlated effect
OILP	Oil price	**INC**	Income
WDI	World development indicators	**ECM**	Error correction model

studied how economic policy uncertainty affects 52 Chinese energy companies. They found that when the economic policy is uncertain, there is a significant decrease in investments in green energy businesses. Shafiullah *et al.* (2021) looked at how uncertainty in economic policies affects the use of renewable energy in the United States. They used data collected monthly for their research. They found out that when people are unsure about the state of the economy, they are less likely to use or buy renewable energy. Their data also shows a two-way relationship between uncertainty in economic policies and the demand for renewable energy. Zhang *et al.* (2021) studied how uncertainty in economic policies affects the demand for renewable energy in the BRIC economies. Their research shows that when there is uncertainty about economic policies, people tend to use less renewable energy. Sohail *et al.* (2021) used the ARDL to study how economic uncertainty affects the use of renewable energy in the United States. They found that when the economy is uncertain, the demand for renewable energy goes down in a bad way. Appiah-Otoo (2021) studied how uncertainty in economic policy affects the use of renewable energy in 20 different countries. It was observed that economic policy uncertainty does have a negative influence on the usage of renewable energy, but this influence is not considered to be significant. At the same time, Magazzino *et al.* (2021) investigate the relationship between renewable energy consumption and economic growth in Brazil amidst the COVID-19 pandemic. The study employed an Artificial Neural Networks (ANNs) experiment in Machine Learning to check if a more intensive use of renewable energy could generate a positive GDP acceleration in Brazil. The results confirm that a greater renewable energy use may sustain the economic growth process.

Financial Globalisation and Renewable Energy Consumption Nexus

Globalisation of finances greatly helps the demand for renewable energy by sharing innovative technologies between different countries. This leads to more use of renewable energy. For instance, Padhan *et al.* (2020) studied how globalisation affected the use of renewable energy in a group of OECD countries from 1970 to 2015. Their research shows that globalisation greatly helps to use more renewable energy. In the same way, Gozgor *et al.* (2016). A study conducted in 2020 looked at how economic globalisation affects the use of renewable energy. The researchers studied data from 30 countries in the OECD from 1970 to 2015. They found that when economic globalisation is higher, there is also higher usage of renewable energy. Koengkan *et al.* (2020) used the ARDL to study how globalisation affected the use of renewable energy in ten Latin American countries from 1980 to 2014. Their research shows that globalisation is beneficial for using renewable energy. Acheampong *et al.* (2021) studied how globalisation (which includes political, social, and economic changes happening worldwide) affected the amount of energy needed and the growth of the economy in 23 developing countries between 1970 and 2015. The research results showed that these three measures of globalisation do not have a significant effect on energy usage.

Ojekemi *et al.* (2023) examine the influence of renewable energy consumption, economic risk, and financial risk on the load capacity factor (LF) within the BRICS countries using FMOLS and DOLS. The findings show that fossil fuels and economic growth cause LF to decrease, while economic risk and the use of renewable energy sources increase the deepening of the LF. This indicates that policies for renewable energy consumption, financial risk, renewable energy, and economic growth can all have an impact on the degree of ecological quality factor. Likewise, Magazzino *et al.* (2022) investigate the relationship among GDP, CO_2 emissions, and renewable energy use. The study uses 5 Scandinavian economies' data sets from 1990 to 2018. The result of the empirical analysis reveals that renewable energy consumption is a useful policy instrument to reduce CO_2 emissions without negatively affecting GDP growth.

Oil Price and Renewable Energy Consumption

In the past 10 years, there has been much research on energy and the economy. This is because people are worried about the harm caused by releasing more carbon dioxide into the air. There have been many things that have caused greenhouse gas emissions to go up all over the world. People have been trying to figure out different ways to decrease these emissions during a certain period. Researchers have always been curious about how the cost of oil impacts the need for sustainable energy. Our examination focused on a research project that investigated the impact of oil prices on the adoption of renewable energy across various nations. The impact of oil prices, economic growth, and CO_2 emissions on renewable energy consumption in G7 nations was explored by Sadorsky (2009b) in his study. They used different methods to analyse these variables. We made an estimate using information from each year between 1980 and 2005. He found out that even though the money each person in a country makes and the amount of CO2 pollution they create have a positive and important effect on REC, the cost of oil has a negative effect. Marques and Fuinhas (2011) conducted a study utilising the GMM method to analyse the correlation between oil prices and REC. They found that the impact was not very important for 24 European Union countries. Salim and Rafiq (2012) studied six developing countries to understand the connection between renewable energy consumption (REC), real gross domestic product (GDP), and the price of oil. They used different methods like panel FMOLS, DOLS, and ARDL to analyse this relationship. According to the research, the price of oil has a bad and important effect on REC in China and Indonesia. However, in Brazil, India, Philippines, and Turkey, this is not true.

Additionally, the findings from the panel DOLS and FMOLS showed that the impact of oil prices is not statistically important. Payne (2012) conducted a study on the correlation between real oil prices and REC in the USA from 1949 to 2009 using the Toda-Yamamoto causal relationship test. The test showed that there was no evidence to suggest that one caused the other. A study by Apergis and Payne (2014) looked at data from 1980 to 2011 to understand how changes in oil prices affected renewable energy consumption in 25 countries that are part of the Organisation for Economic Cooperation and Development (OECD). They found that when the price of oil goes up, the REC also goes up over time. Azad and colleagues In 2014, a study focused on Australia, while another study done in 2015 looked at eleven South American countries, as mentioned by Apergis and Payne (2019) found that this relationship is not consistent across all countries. In 2020, it was found that the price of oil has a good impact on renewable energy consumption in OECD countries. In addition, Chen *et al.* (2021), in certain undemocratic nations, a recent study conducted in 2021 revealed that actual oil prices play a constructive role in promoting the utilisation of renewable energy.

Most of the studies examined how the growth of finances influences the desire for renewable energy. The results they found are unclear and probably different depending on how many people were in the study, how long the study lasted, and which country they investigated. In addition, it is crucial to take into account the management of policies by the 11 countries that belong to OPEC, particularly during times of uncertainty, and their collaboration with other economies to enhance their capacity for renewable energy production. This should be kept in mind when conducting a real-life assessment. The specific influence of the correlation between the global economy, oil prices, uncertain economic policies, income, and the demand for renewable energy on the 11 OPEC nations has yet to be studied. These countries are doing well in developing their ability to create renewable energy. This is attracting more investment from other countries, and they are also trying hard to keep their economies growing. They are also working towards creating a strong financial system.

Theoretical Framework

The Organisation of Petroleum Exporting Countries' (OPEC) economies have a high growth potential, which is mostly fuelled by fossil fuel-based initiatives and complimented by the cross-border mobility of resources, which is attributable to globalisation. Besides these considerations, the availability of natural resources has provided these countries the ability to drive economic expansion. The predominance of continuous growth in the economy has resulted in a steady increase in pollution in many nations, prompting governments to implement policies necessary to encourage the use of cleaner energy. The use of renewable energy by nations is now more significantly shaped by the unpredictability of economic policies and the expanding global integration of financial sectors. According to Gozgor *et al.* (2020), the increased integration of finances across the globe greatly helps to increase the use of renewable energy. Capital and financial assets are influenced by the uncertainty of economic policies, as indicated by research. Moreover, they noticed that when countries share their financial resources globally, it helps to increase the production of clean and sustainable energy. This is done by transferring the technology from one country to another. Quite a number of studies found that economic policy uncertainty increases the use of renewable energy (Koengkan *et al.,* 2020; Padhan *et al.,* 2020; Gozgor *et al.,* 2020). The rising cost of oil has compelled individuals to turn to renewable energy sources, thereby promoting their widespread use. In 2020, make this text easier to understand. Income can either help or hinder the use of renewable energy through money and services. Lastly, the amount of money people make can affect how much renewable energy they use. This depends on whether countries choose to keep using old, traditional forms of energy or switch to renewable energy options. The study incorporates income (GDP) in the model in line with previous works (He *et al.,* 2021; Shan *et al.,* 2021; Sarkodie *et al.,* 2021; Awosusi *et al.,* 2022). The relationship is anticipated to be positive. This is because most developing nations including the sampled countries, prefer economic expansion at the expense of the quality of the environment. This stage is known as the scale effect stage, and it is paramount to emerging nations. The role of globalisation in renewable energy is mixed. In line with the work of Kihombo *et al.* (2021) and Kirikkaleli *et al.* (2021), globalisation is incorporated into the framework. Globalisation boosts competitiveness and therefore, represents a significant danger to the environment by expanding the flow of products and services.

Based on the information given earlier, the general energy usage function is represented like this:

$$REC_{it} = f(EPU_{it} + FG_{it} + OILP_{it} + INC_{it} + \varepsilon_{it}) \quad (1)$$

where REC_{it}, EPU_{it}, FG_{it}, $OILP_{it}$, INC_{it} and, ε_{it} represent renewable energy consumption, economic policy uncertainty, financial globalisation, income, and error term respectively. Similarly, countries and periods are represented by subscripts i = (1, ..., N) and period t = (1, ...,T).

Data

This analysis is carried out using annual data for 11 OPEC member countries (Algeria, Angola, Congo, Kuwait, Gabon, Iraq, Libya, Nigeria, Saudi Arabia, the United Arab Emirates, and Venezuela) from 2000M01 to 2020M12. These economies are based on World Bank criteria that these OPEC economies remain heavily reliant on fossil fuels. Oil-based energy has mostly remained the main driving force of the economy in terms of global exchange earnings, as well as the primary source of energy for rising energy consumption in these countries.

The amount of renewable energy consumption is measured using renewable energy consumption (% of total final energy consumption), which is the Renewable energy consumption is the share of renewable energy in total final energy consumption (WDI, 2023).

The Economic Policy Uncertainty Index (EPUI) is an indicator used for measuring economic policy uncertainty. The index is developed based on newspaper coverage frequency, which was aimed to capture uncertainty about who will make economic policy decisions, what economic policy actions will be undertaken and when, and the economic effects of policy actions (or inaction) – including uncertainties related to the economic ramifications of "non-economic" policy matters, e.g., military actions. The measure captures both near-term concerns (e.g., when will the Fed adjust its policy rate) and longer-term concerns (e.g., how to fund entitlement programs).

The study measures the oil prices by using crude oil price uncertainty in the main analysis. We use the daily closing oil price for the nearest contract to maturity of West daily West Texas Intermediate (WTI, 2023) futures. We calculate the annual oil price uncertainty as the standard deviation of daily returns of oil prices (Farouq and Sulong, 2020). Gross domestic per capita (GDP) is used as the proxy for Income, which is generated from World Development Indicators (2023). In this study, financial globalisation is measured through the KAOPEN. This index was generated by Chinn and Ito (2007) and this was later updated in 2019. It is based on the binary dummy variables which codify the restrictions on the economies' financial transactions as reported by the IMF's Annual Report. The index comprises four dummy variables on the restrictions of foreign accounts. This includes a variable showing the presence of multiple exchange rates, a variable highlighting restrictions on current account transactions, a variable representing restrictions on capital account transactions, and a variable showing the requirement for the surrender of export proceeds. The measure has been widely used in previous studies such as Didžgalvytė and Osteikaitė (2018); De Mendonça *et al.* (2019); Farouq and Sulong (2023); Bui *et al.* (2019); and Nguea (2020).

Estimation Strategy

In recent empirical studies, cross-sectional dependence of macroeconomic determinants across countries has received much attention. Presently, cross-sectional dependence is perceived as a basic rule rather than an expectation among cross-sectional units (Moradbeigi & Law, 2017; Meo *et al.,* 2022). This is to avoid having a misleading result while ignoring the likelihood of cross-country dependence (Hsiao & Tahmiscioglu, 2008). In view of that and coupled with the fact that the sampled economies are linked to each other in terms of trade and other related activities, it is likely that data from these economies may display cross-sectional dependencies. Therefore, the first step of our analysis is to test for the presence or absence of these likely dependencies in the panels. Secondly, ignoring heterogeneity issues in the slope coefficients could provide inaccurate estimation results that could lead to biased inferences (Breitung, 2005; Musah *et al.,* 2020). Testing for heterogeneity will enable the study to identify whether the parameters are homogeneous or heterogeneous across the series. That will empirically affirm the assumption of first or second-generation methods concerning the current study. This article tests the homogeneity of the data set to establish reasonable evidence that the use of heterogeneous techniques is required. As such, the test was developed by Pesaran and Yamagata (2008). While the heterogeneity and dependency nature of the data is ascertained, we then check the stationarity properties of the variables. This study uses two-unit root tests i.e., the second-generation methods of Cross-sectional Augmented Dickey-Fuller (2006) (CADF) and Cross-sectional ImPesaran (2007) (CIPS). In this study, we used STATA 15 and Eviews 11 for the analysis.

Cross-sectional Dependency Test

Cross-sectional dependence is the most frequently encountered issue in panel sequence analysis. The CD problem could emerge as a result of unobserved disturbances that bias the results. To solve this issue, we use Pesaran's (2004) approach as follows:

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

where shows the pair-wise correlation residual estimate sample, while T & N are for cross-sections and periods.

Slope Homogeneity Tests

Not considering the differences in slope coefficients may give incorrect estimates which could result in wrong conclusions. Testing for heterogeneity means checking if the properties are the same or different throughout the series. We will gather evidence to prove or disprove the assumptions made by previous studies in this research. This research tests if the data set is similar throughout and provides evidence that a different technique might be needed if the data is not similar. The study used a test made by Pesaran and Yamagata (2008), which is an updated version of the Swamy (1970) test. Swamy (1970) uses the dispersion estimates of individual slopes from a combined estimator to test for similarity. Swamy's test is used for data where the number of observations (N) is not very large and the number of periods (T) is large. In simpler terms, Pesaran and Yamagata (2008) made changes to the test so that it could work with panel data that has a large number of groups. The time-series part is also very big. This test checks if the two models are similar by comparing them. The restricted model is a way to estimate fixed effects where the slopes of the variables are forced to be the same. The unit-specific cross-sectional ordinary least squares is the unrestricted model. This analysis reached its conclusion by examining the differences between the two models. The significant figures observed in the test statistic indicate a notable disparity between the fixed effects and the unit-specific estimates. As a result, we can conclude that the null hypothesis of slope homogeneity is not valid. Furthermore, this test offers the advantage of being able to handle both balanced and unbalanced data sets in panel analyses.

Therefore, after examining the cross-sectional connection, it is necessary to examine the slope homogeneity because nations may vary in terms of population, finance, and socioeconomic structure. To accomplish this goal, the Pesaran and Yamagata (2008) slope homogeneity test is used. The following are the assessment equations:

$$\Delta_{Sh} = (N)\frac{1}{2}(2f)\frac{1}{2}\left[\frac{1}{N}S - f\right] \quad (3)$$

$$\Delta_{ASh} = (N)\frac{1}{2}\left(\frac{2f(T-f-1}{T+1}\right)\frac{1}{2}\left[\frac{1}{N}S - f\right] \quad (4)$$

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

Unit Root Test

In the last 10 years, many people have been interested in testing for unit roots in panel data. Most of this research presumed that each set of data in the group was distributed independently from each other. This is a very narrow assumption, especially when looking at comparisons between different countries. In regular panel data analysis, we deal with the correlation between different groups by including a time factor that remains the same for each group but changes over time. After completing the initial tests and determining the unit root, the next step is to understand if the variables in the study are stationary. This study uses two tests to check if something is stable over time. Observations from the cross-sectional dependency test demonstrate the presence of a dependency among the various series. The research advises the utilisation of panel second-generation unit root tests due to this reason. There exists a wide range of techniques available for conducting the panel unit root test. This study uses updated methods called CADF 2006 and CIPS 2007. These methods help analyse data more effectively.

Second-generation unit root evaluations are required to examine the combined properties of components while evaluating the CD and heterogeneity in slope coefficients. Pesaran

(2007) cross-sectional augmented Dickey-Fuller (CADF) and Pesaran-Shin (CIPS) unit tests are used in this respect. These unit root checks work best towards heterogeneous panel data and exceed the first-generation unit root test in terms of effectiveness and dependability.

Cross-sectional Augmented Dickey-fuller (CADF) Panel Unit Root Test

The research uses a test called CIPS, developed by Pesaran (2006), to check if the variables are stable. We are using unit root testing to analyse the data in each section of the panel. This is done using CADF. This means that it is checking if the sequence is consistent or not in each part of the panel. The CADF test assumes that each economy is influenced by different factors at different times and in certain situations, where N is greater than T, and T is greater than N. This is about how things around each other are related. We compare the test numbers with the critical numbers. If the numbers are the same or lower, then the country is not changing. The guidelines say that if the CADF's critical value is lower than its statistics value, then we can reject the null hypothesis. This means that only the series of data from that specific country is considered to be stationary. The numbers used to determine the results of the CADF test are estimated like this:

$$Y_{i,t} = (1 - \varphi_i)\alpha_i + \varphi_i y_{i,t-1} + \pi_{i,t} \tag{5}$$

$$i = 1,2,3,\dots\dots\dots, N \text{ and } t = 1,2,3,\dots\dots\dots.., T \tag{6}$$

$$\pi_{it} = \gamma_i f_t + \mu_{it} \quad () \tag{7}$$

Here f_t displays the unobservable common influence of each country, reveals the error of individual-specific. Equations 1 and 2, as well as the unit root hypothesis, can be given as follows:

$$\Delta y_{it} = \delta_i + \beta y_{i,t-1} + \tau_i f_i + \mu_{it}$$
$$i = 1,2,3,\dots\dots, N \text{ and } t = 1,2,3,\dots\dots.., T \tag{8}$$

H_0:β_i = 0 upon all i (non-stationarity H_1:β_i< 0i = 1,2,3,…,N_1 *β_i = o i* = N_1+1, N_1+*2,………,N (the series is stationary)*

Cross-sectional Im-pesaran (CIPS)

The CIPS test is a type of unit root test created by Pesaran (2007). Very different from the first group, which included Levin, Lin, Madalla, and Wu. This is because the second-generation tests can consider the relationship between different observations and can work even if the null hypothesis assumes that there is no constant pattern or trend in the data. Pesaran used common factors by finding the average of past values in the series. The CIPS t-statistic is obtained by averaging the ADF t-statistics for every section.

$$CIPS = N^{-1}\sum_{i=1}^{N} t_i(N,T) \tag{9}$$

where, t_i (*N,T*) is the t-statistic of the slope.

Cointegration Test

After determining that the variables are not changing, a long-term connection between them is established. In this study, we used the Westerlund (2007) ECM panel cointegration test. This test gives good results when there are differences in slopes and relatedness between groups. The analysis of the relationships among financial globalisation, oil price, economic policy uncertainty, income, and renewable energy demand in 11 OPEC member countries is conducted in this study using a technique called cointegration, initially presented by Westerlund (2007). As stated by Kapetanios (2011), this test works well and is accurate when the errors are related to each other. The math problems are written below:

$$\delta i(L)\Delta y_{it} = y2_{it} + \beta_i(y_{it} - 1 - \delta_i x_{it}) +$$

$$\aleph_i(L)V_{it} + \varphi_i \tag{10}$$

The test statistics of this technique are given below:

$$G_t = \frac{1}{N}\sum_{i-1}^{N}\frac{\delta_i}{SE(\delta_i)} \tag{11}$$

$$the\ G_\delta = \frac{1}{N}\sum_{i-1}^{N}\frac{Y\delta_i}{\delta_i(1)} \quad (12)$$

$$P_r = \frac{\delta}{SE(\delta)} \quad (13)$$

$$P_\delta = Y\delta$$

where Equations 8 and 9 show the group means statistics involving Ga and Gt. While equations 10 and 11 denote the panel statistics involving Pa and Pt. The technique has both null and alternate hypotheses of "no cointegration" as well as "cointegration," accordingly.

Dynamic Common Correlated Effect Estimation

Economists suggested different statistical methods for studying panel data in real-life situations. However, because cross-sectional dependency and heterogeneity exist in panel data, using first-generation techniques like Fully modified ordinary least squares may lead to biased outcomes. The DCCE estimator developed by Chudik and Pesaran (2015) is capable of tackling issues of non-stationarity, endogeneity, cross-sectional dependence, and heterogeneity. The DCCE considers the fact that different things or variables might be related to each other. This method considers different slopes and the relationship between different data points by taking into account average values and previous data. Moreover, this method is effective for small sample sizes because it employs the jack-knife correction method (Chudik & Pesaran, 2015). In the research conducted by Chudik and Pesaran (2015b), they used the following equation to describe how things change over time:

$$REC_{it} = \delta_i REC_{it-1} + \alpha_i\omega_{it} + \sum_{P=0}^{Pr}\gamma\omega ip\,\bar{X}_{t-p} + \sum_{P=0}^{Pr}\gamma yip\,\bar{Y}_{t-p} + \mu_{it} \quad (15)$$

For this work, REC stands for ecological footprint, is the lag of REC, while represents the explanatory variables, and refers to the limit of lags incorporated in the cross-section averages.

Results and Discussion

Descriptive Statistics and Correlation Analysis

The expressive rundown and relationship examination for the 11 OPEC part nations appear in Tables 2 and 3 separately. Table 1 gives the portrayal of all the factors utilised in this think about, their units of estimation, standard deviations, implies, skewness, and kurtosis in connection to the inspected economies from 2000M01 to 2020M12. The factors for this inquiry are renewable vitality utilisation (REC), monetary globalisation (FG), oil cost (OILP), financial approach vulnerability (EPU), and salary (INC). The Kurtosis and Skewness values show deviated information dispersion. However, on the off chance that the comes about for Kurtosis and Skewness are three, individually, at that point demonstrates that the information is regularly dispersed. The normal recurrence disseminations were given by the variables' Jarque-Bera measurements coefficients. The Table unmistakably shows that the degree of natural quality (REC) on normal is 4.076 with a comparing standard deviation of 1.029. So also, the normal esteem of OILP is 4.490 which relates to the standard deviation of 1.027, compared to the cruel esteem of 1.464 which compares to the standard deviation of 0.721 in the financial approach vulnerability. The cruel esteem of wage is 6.530, which matches the standard deviation of 1.1919. At the same time, monetary globalisation is 2.091 on normal with the comparing 1.051 standard deviations. Eminently, all the factors display significant fluctuation between the nations, which clarifies why the standard deviations are smaller than the midpoints for the perceptions.

Meanwhile, the corresponding correlation matrix is presented along with the summary statistics. Table 2 shows the results of the used variables in the current study, thereby analysing the possibility of having the problem of multi-collinearity among the scrutinised variables. The Table provides the correlation coefficients of all the variables which help the modelling and aid in confirming the selection of instruments. In the result, based on the accompanying correlation values, none of the variables appear to have any problem with multicollinearity in the study.

Result of Cross-section Dependence Test

The CD test result, derived by estimating Equation 4, is reported in Table 3 as evidence of the prevalence of CD in panel data by denying the null hypothesis at the 1% level of significance. As such, there is a high degree of dependency between states, implying that any shock to one of the sampled countries would influence other sectors of these countries.

Slope Homogeneity Result

The study goes on to examine homogeneity to identify the best panel methodologies to use properly. Table 4.4 summarises the study's homogeneity test results. Given the probable values of the delta and adjusted delta, as well as the corresponding P-values, the analysis decisively rejects the null hypothesis coefficients of homogeneity at a 1% significance level.

Table 2: Descriptive statistics summary

Variables	Mean	Standard deviation	Skewness	Kurtosis	Jarque-Bera	CV
$lnREC_{it}$	4.076	1.029	0.109	3.293	59.960* (0.000)	0.252
$lnOILP_{it}$	4.490	1.027	0.377	1.919	22.051* (0.000)	0.229
$lnEPU_{it}$	1.464	0.721	0.468	1.252	39.346 (0.000)	0.492
$lnINC_{it}$	6.530	1.919	0.252	2.689	46.026 (0.000)	0.294
lnFG	2.091	1.051	0.426	1.968	44.664 (0.000)	0.503

Note: * Shows statistical significance at a 1% level, while ** signifies the 5% significance level, () symbolises the p-value, Coefficient of Variation (CV). Source: WDI (2023); WTI (2023); EPUI (2023); KAOPEN (2019).

Table 3: Correlation matrix summary

	$lnREC_{it}$	$lnOILP_{it}$	$lnFD_{it}$	$lnINC_{it}$	$lnICT_{it}$
$lnREC_{it}$	1.000				
$lnOILP_{it}$	0.056 (0.005)	1.000			
$lnEPU_{it}$	0.215 (0.000)	0.073 (0.257)	1.000		
$lnINC_{it}$	0.0155 (0.808)	0.065 (0.000)	0.003 (0.961)	1.000	
$lnFG_{it}$	0.208 (0.001)	0.042 (0.259)	0.298 (0.000)	0.196 (0.001)	1.000

Note: * Shows statistical significance at a 1% level, while ** signifies the 5% significance level, () symbolises the p-value, Coefficient of Variation (CV). Source: WDI (2023); WTI (2023); EPUI (2023); KAOPEN (2019).

Unit Root Result

To identify a possible long-term linkage between parameters, the integrating qualities of each factor utilised in the panel must be determined (Balsalobre-Lorente *et al.,* 2020). We used CADF and CIPS to figure out whether or not the parameters REC, OILP, EPU, INC, and FG have unit roots. They are used to track the integration order and investigate the possibility of co-integration between parameters. Table 4.5 summarises the results of the panel unit root testing. The empirical results of the CADF and CIPS tests reveal that there is no unit root at the level and first difference in all the variables used in this study.

Co-integration Test Analysis

The Table below displays the cointegration relationship between FG, OILP, EPU, INC, and REC, is a result of Westerlund cointegration analysis. The results show that the null hypothesis of no co-integration is thus rejected at constant and trend given that the group statistics (G_t and G_) and panel statistics (P_t and P_) become significant at 1% and 1%, respectively. This suggests a long-term connection between financial globalisation, oil price, economic policy uncertainty, income, and renewable energy demand. This is in line with Bayar *et al*. (2020).

Discussion of the Results

Table 8 shows the estimation results for the 11 OPEC member states. Inside the square parentheses are the t-statistics. The CD Pesaran figures and related P-values evaluating for cross-dependence in the models demonstrate that the results reject the null hypothesis, indicating a substantial cross-sectional dependence among the sampled countries (p-value 0.005). The value of R2, which indicates the goodness-

Table 4: Cross-sectional dependence tests

Variables	Pesaran's CD test	Breush-Pagan (LM) test
$lnREC_{it}$	3.852* (0.000)	85.677* (0.000)
$lnOILP_{it}$	2.756* (0.000)	22.559* (0.000)
$lnEPU_{it}$	1.993** (0.046)	19.149** (0.038)
$lnINC_{it}$	2.639** (0.008)	22.039** (0.014)
$lnFG_{it}$	2.928* (0.003)	24.201* (0.007)

Note: * Shows statistical significance at a 1% level, while ** signifies the 5% significance level, () symbolises the p-value. Source: WDI (2023); WTI (2023); EPUI (2023); KAOPEN (2019).

Table 5: Slope homogeneity tests

Group	Statistic
Delta	-2.091**
Adjusted Delta	-2.209**

Note: * Shows statistical significance at a 1% level, while ** signifies the 5% significance level. Source: WDI (2023); WTI (2023); EPUI (2023); KAOPEN (2019).

Table 6: Panel unit root test

Variables	CIPS		CADF	
	At Level	At First Different	At Level Z[t-bar]	At the First Diff Z[t-bar]
$lnREC_{it}$	-5.058 (-3.06)	-6.420* (-3.06)	-4.606* (0.000)	-7.415* (0.000)
$lnOILP_{it}$	-5.740* (-3.06)	-6.520* (-3.06)	-4.262* (0.000)	-7.669* (0.000)
$lnEPU_{it}$	-3.959* (-3.06)	-6.190* (-3.06)	-4.534* (0.000)	-5.985* (0.000)
$lnINC_{it}$	-4.643* (-3.06)	-6.240* (-3.06)	-3.650* (0.000)	-6.406* (0.000)
$lnFG_{it}$	-4.659* (-3.06)	-6.230* (-3.06)	-3.645* (0.000)	-6.431* (0.000)

Note: * Shows statistical significance at a 1%level, while ** signifies the 5% significance level, () symbolises the t-bar. Source: WDI (2023); WTI (2023); EPUI (2023); KAOPEN (2019).

Table 7: Summary Results of Heterogeneous Co-integration Tests

Statistic	With Trend Value	Without Trend Value
G_t	-3.743* (0.004)	-3.498 (0.001)
G_a	-19.813 (0.117)	-17.971** (0.013)
P_t	-9.100* (0.000)	-8.414* (0.000)
P_a	-20.802* (0.006)	-18.453* (0.000)

Note: * Shows statistical significance at a 1% level, while ** signifies the 5% significance level, () symbolises the p-value. Source: WDI (2023); WTI (2023); EPUI (2023); KAOPEN (2019).

of-fit associated with the model, suggests that the model explained 62% of cross-country variability. Meanwhile, the F-value of 94.251, which indicates a 1% significance, indicates that the variables are jointly significant. Therefore, the statistical analysis of the model compares the combined effect of all factors, revealing that EPU and OILP are adversely linked with the REC. Whereas INC is insignificant, FG is both positive and statistically significant about REC. The coefficients of these associations for EPUit and OIPit are negative and significant at 1%, except for INCit, which is negligible. Nevertheless, the FG is significant at the 5% level.

First, the findings demonstrate that EPU is significant and has a negative relationship with REC. More precisely, a 1% change in EPU results in a 0.029% decrease in REC. It suggests that ambiguity in government economic policies, particularly in these OPEC member nations, has decreased during the REC transition and it is regarded as a risk factor in influencing community and industrial behaviour. These findings are consistent with those of Algharabali and Alabdulghafour (2020), who contend that EPU is closely related to micro and macroeconomic changes in any country, financial markets, and business behaviour. Shafiullah *et al.* (2021) use a non-linear econometric approach to determine the influence of EPU on estimating the shift in the use of energy from sources of clean energy in the United States. The long-term relationship

Table 8: Dynamic common correlated effect estimate

DCCE			
Variables	**Coef. (Std. Err.)**	**Z**	**P-value**
REC_{it-1}	-0.493 (0.114)	-4.331	0.000
EPU_{it}	-0.029 (0.012)	-2.313	0.000
FG_{it}	2.980 (1.198)	2.49	0.013
$OILP_{it}$	-0.104 (0.039)	-2.67	0.008
INC_{it}	0.217 (0.484)	0.44	0.654
Constant	-0.117 (0.056)	-2.09	0.040
N	**11**		
R-squared	0.62		
Adj. R-squared	0.55		
F (94, 251) 2.7	(0.000)		
CD Statistic 3.51	(0.000)		

Note: * Shows statistical significance at a 1% level, while ** signifies the 5% significance level, () symbolises the Std. Error.
Source: Source: WDI (2023); WTI (2023); EPUI (2023); KAOPEN (2019).

findings indicate EPU's negative and considerable effect on REC in the United States. Based on the empirical findings, it is advised that national policymakers and business agents maintain consistency in their economic policies to increase the use of energy from renewable sources. On the other hand, the result contradicts the findings of Feng and Zheng (2022) where their results indicate that economic policy uncertainty exerts a positive effect on renewable energy.

Second, our findings demonstrate that financial globalisation is critical in promoting renewable energy usage in the OPEC member states studied. Financial globalisation can help to improve environmental quality by expanding the usage of renewable energy. Our outcomes are consistent with those of Shahbaz *et al.* (2016) regarding India, which shows that globalisation reduces overall energy demand while improving environmental quality by boosting clean energy. Similarly, Xu *et al.* (2023), Chen *et al.* (2021), Ulucak *et al.* (2020) also found a positive effect on load capacity factor in Brazil.

Third, the outcome of oil prices has a statistically significant and negative effect on the utilisation of renewable energy. Owing to the negative coefficient of oil prices, many nations continue to profit from rising oil prices, obstructing the transition towards renewable energy sources. The results of this study align with the results obtained by Mukhtarov *et al.* (2022) in the case of Iran, Joof *et al.* (2023) in the case of China, Deniz (2019) in the case of Azerbaijan, Mukhtarov *et al.* (2021) in the case of Kazakhstan, and Karacan *et al.* (2021) in the case of Russia.

Fourth, income does not appear to be having a statistically significant impact on renewable energy consumption. Income with an insignificant effect suggests that these countries have failed to shift their expanding revenues away from traditional sources of energy and focus on renewable energy supply instead. Our result is consistent with Dabboussi and Abid (2022) in the case of the USA, Karaaslan and Çamkaya (2022) in the case of Turkey, Omri and Nguyen (2014) for low-income countries and Deniz (2019) for oil-exporting and importing countries. However, the result contradicts the findings of Magazzino (2017) in a study conducted in Italy.

Robustness Test

To verify our findings, we perform an alternative estimation technique. Initially, we implement the dynamic common correlated effects estimation. The outcomes of all the concerned variables using DCCE are reported in Table 8. Overall, the long-run CS-ARDL coefficients confirm the findings that we have previously discussed using DCCE. The coefficients derived from the CS-ARDL estimator are robust and reliable, as they account for cross-sectional dependence and allow for heterogeneous slope coefficients across panel observations (Paramati *et al.,* 2017). We present the results of the CS-ARDL estimator in Table 9 below. Likewise, the outcomes are found to be in line with the estimates of the DCCE estimator, except for the *INC* variable which turns out to be significant in the short run. The positive and significant relationship is in line with the findings of Chen (2022).

Conclusion

In the present study, we examined the factors of renewable energy demand in 11 OPEC member nations' panel data from 2000M01 to 2020M12. The effects of economic policy uncertainty on renewable energy demand are given distinctive importance. The long-term coefficients are calculated using the DCCE modelling technique. We discover that the demand for renewable energy is positively impacted by financial globalisation. In addition, a higher degree of financial globalisation in the panel dataset of the

Table 9: Cross-sectional ARDL Robustness Test

	Coef.	**Std. Err.**	**z**	**P > z**
Short Run Est.				
EPU_{it}	-0.201	0.054	-3.72	0.000
FG_{it}	0.451	0.104	4.34	0.000
$OILP_{it}$	-0.221	0.061	-3.62	0.000
INC_{it}	0.048	0.021	2.29	0.028
Adjust. Term	-0.421	0.128	-3.29	0.000
*Ir*_EPU_{it}	-0.025	0.012	-2.08	0.042
Ir_FG_{it}	0.372	0.051	7.29	0.000
Ir_$OILP_{it}$	-0.312	0.055	-5.67	0.000
Ir_INC_{it}	0.015	0.029	0.51	0.579
R-squared	0.60			
Adj. R-squared	0.55			
F(99, 185)	3.68	(0.000)		
CD Statistic	3.27	(0.000)		

Note: * Shows statistical significance at a 1% level, while ** signifies the 5% significance level, () symbolises the p-values.
Source: WDI (2023); WTI (2023); EPUI (2023); KAOPEN (2019).

nations tested encourages the need for renewable energy. The findings also demonstrate that there is a detrimental long-term association between EPU and REC. This suggests that the economic policy uncertainty of these countries is slowing down the transfer to renewable energy sources and is seen as a risk factor for influencing social and economic behaviour. Although income may seem inconsequential, it indicates that these countries have not used their expanding wealth to divert away from traditional energy sources for green energy supplies. Oil prices, however, harm the adoption of renewable energy. These nations continue to profit from rising oil prices as a result of this adverse coefficient, disregarding the renewable energy transition goal.

In the context of these OPEC members, increasing the use of renewable resources in the manufacturing process can lessen the harmful effects of environmental degradation and global warming. According to what we have discovered, advancing globalisation's financial facets will benefit renewable energy. By doing so, it can prevent pollution and global warming from having a negative long-term impact on living things and natural environments. As a result, we must increase our understanding of how globalisation supports renewable energy, not just for OPEC members but also for other developing nations. In this situation, the expansion of the stock market may play a positive role in the effort to cut carbon emissions across the board, including in these OPEC members as well as emerging and developing countries. In this regard, OPEC nations may be able to cut their carbon emissions provided they develop a successful strategy for funding clean energy and establish a strong organisational and regulatory atmosphere. Moreover, there is a good possibility to obtain and sustainably use higher levels of oil money amid higher oil prices for countries with vast resources where oil income makes up over 50% of GDP. Given this context, our findings of the adverse effect of increased oil prices on renewable energy demand can be interpreted as neglect on the side of these countries to transform the growing oil revenues during increased oil prices into greater environmentally conscious and efficient energy sources, which include renewable energies. In a nutshell, based on our analyses, these countries are less liberal in investing in alternative energy sources when traditional energy prices are greater than usual. It is advised that higher oil revenues be used to achieve an appropriate degree of funding and development in green and sustainable energy sources.

Policy implication

This paper gives some important information that can be used by relevant policymakers, investors, and producers of goods and services. The main goal of policymakers is not to set a fixed policy expectation for renewable energy innovators. Instead, they want to remind them of the risks involved, which may happen at any time. Because it is very hard to create new renewable energy technologies, some firms depend on funds from the government to keep running. This is not good for the long-term transition to a clean energy system. Our findings do not fully show that renewable energy development and innovation do not need a consistent policy environment. However, they support the idea that when there is pressure from the market, it is more likely for innovations in renewable energy to occur. Cheng *et al.* (2017) argue that when the government tries to control and protect people too much, it can affect how well businesses can come up with new ideas and products. If the government provides too much support to renewable energy, it could make innovators less interested in creating new and risky technology because there is not much competition in the market. The EPU is warning about potential risks for future support policies. This can remind investors about market risks and encourage companies to get involved in renewable energy innovation. Also, investors can use the connection between economic policy uncertainty (EPU) and renewable energy innovation to start their investment plans.

Usually, when EPU is high, it indicates that financial investment is not a good idea because real investment is likely to be postponed. While there may be some conflicting information, increasing investments in renewable energy will be advantageous during times of environmental policy uncertainty (EPU). Investors can feel more sure about investing in renewable energy and take advantage of the opportunity when dealing with EPU. To put it simply, producers need to focus on being more innovative and take advantage of the opportunities from EPU to become leaders in the market. We can understand that the effect of EPU on renewable energy innovation depends on how much value is given to the choices of real options and growth options. If producers are better at coming up with new ideas, they will get more benefits from innovation. This means they can get more advantages from EPU. In this situation, the people making the products need to improve their ability to come up with new ideas so that they can have more chances to grow.

So, based on these findings, it would be good for the governments to come up with plans to slowly encourage the use of revenues generated from oil for cleaner energy production. More importantly, it is recommended to remove trade barriers to allow the flow of renewable energy into these oil-rich economies, as there are great opportunities for trade in this area. For example, these countries can expect to bring in electricity made from water power from Nepal and bring in energy made from heat from Bhutan. Although it is often difficult for oil-rich countries to trade power due to political and economic issues, it is important to overcome these obstacles in order to achieve the SDG (Sustainable Development Goals). This can be done by implementing public policies that encourage the use of renewable energy in these countries.

Research limitations and Future research

Quite a few limitations are connected to this study. The study has analysed only one main source of renewable energy consumption in the 11 OPEC member countries. Many other components like power and solar could be used as a measure. Therefore, future researchers are recommended to pay attention to the other components and enhance the scope of the study by including other key determinants under consideration. This study is based on a limited number of 11 OPEC member economies for the analysis of the effects of economic policy uncertainty, financial globalisation, oil prices, and income on renewable energy consumption. These countries could provide a limited data set, and the research could be applicable in a few similar economies. However, obtaining data from other different regions of the globe could improve the study's generality and reliability.

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Conflict of Interest Statement

The authors declared that they have no conflict of interest.

References

Acheampong, A. O., Boateng, E., Amponsah, M., & Dzator, J. (2021). Revisiting the economic growth - Energy consumption nexus: Does globalization matter? *Energy Economics*, *102*, 105472.

Akram, R., Chen, F., Khalid, F., Ye, Z., & Majeed, M. T. (2020). Heterogeneous effects of energy efficiency and renewable energy on carbon emissions: Evidence from developing countries. *Journal of Cleaner Production*, *247*, 119122.

Anton, S. G., & Nucu, A. E. A. (2020). The effect of financial development on renewable energy consumption. A panel data approach. *Renewable Energy*, *147*, 330-338.

Appiah-Otoo, I. (2021). Impact of economic policy uncertainty on renewable energy growth. *Energy Research Letters*, *2*(1).

Apergis, N., & Payne, J. E. (2014). Renewable energy, output, CO2 emissions, and fossil fuel prices in Central America: Evidence from a nonlinear panel smooth transition vector error correction model. *Energy economics*, *42*, 226-232.

Apergis, N., & Payne, J. E. (2019). Convergence in condominium prices of major US metropolitan areas. *International Journal of Housing Markets and Analysis*, *12*(6), 1113-1126.

Asongu, S. A., & Odhiambo, N. M. (2021). Inequality, finance and renewable energy consumption in Sub-Saharan Africa. *Renewable Energy*, *165*, 678-688.

Asongu, S. A., & De Moor, L. (2017). Financial globalisation dynamic thresholds for financial development: evidence from Africa. *The European Journal of Development Research*, *29*, 192-212.

Awosusi, A., Sethunya, V., & Matambo, T. (2021). Synergistic effect of anaerobic co-digestion of South African food waste with cow manure: Role of low density-polyethylene in process modulation. *Materials Today: Proceedings*, *38*, 793-803.

Bayar, Y., Sasmaz, M. U., & Ozkaya, M. H. (2020). Impact of trade and financial globalization on renewable energy in EU transition economies: A bootstrap panel granger causality test. *Energies*, *14*(1), 19.

Bloch, H., Rafiq, S., & Salim, R. (2015). Economic growth with coal, oil and renewable energy consumption in China: Prospects for fuel substitution. *Economic Modelling*, *44*, 104-115.

Brunnschweiler, C. N. (2010). Finance for renewable energy: An empirical analysis of developing and transition economies. *Environment and Development Economics*, *15*(3), 241-274.

Breitung, J. (2005). A parametric approach to the estimation of cointegration vectors in panel data. *Econometric Reviews*, *24*(2), 151-173.

Bui, D. T., Ngo, P. T. T., Pham, T. D., Jaafari, A., Minh, N. Q., Hoa, P. V., & Samui, P. (2019). A novel hybrid approach based on a swarm intelligence optimised extreme learning machine for flash flood susceptibility mapping. *Catena*, *179*, 184-196.

Chen, W. J. (2022). Toward sustainability: Dynamics of total carbon dioxide emissions, aggregate income, non-renewable energy, and renewable power. *Sustainability*, *14*(5), 2712.

Chen, C., Pinar, M., & Stengos, T. (2021). Determinants of renewable energy consumption: Importance of democratic institutions. *Renewable Energy*, *179*, 75-83.

Chinn, M. D., & Ito, H. (2023). *Measuring Financial Integration: More Data, More Countries, More Expectations* (No. w31505). National Bureau of Economic Research.

Choi, S., Furceri, D., & Yoon, C. (2021). Policy uncertainty and foreign direct investment. *Review of International Economics*, *29*(2), 195-227.

Christou, C., Cunado, J., Gupta, R., & Hassapis, C. (2017). Economic policy uncertainty and stock market returns in PacificRim countries: Evidence based on a Bayesian panel VAR model. *Journal of Multinational Financial Management*, *40*, 92-102.

Chu, L. K., & Le, N. T. M. (2022). Environmental quality and the role of economic policy uncertainty, economic complexity, renewable energy, and energy intensity: The case of G7 countries. *Environmental Science and Pollution Research*, *29*(2), 2866-2882.

Dabboussi, M., & Abid, M. (2022). A comparative study of sectoral renewable energy consumption and GDP in the US: Evidence from a threshold approach. *Renewable Energy*, *192*, 705-715.

De Mendonca, T., & Zhou, Y. (2019). What does targeting ecological sustainability mean for company financial performance? *Business*

Strategy and the Environment, *28*(8), 1583-1593.

Didžgalvytė, M., & Osteikaitė, A. (2018). Relationship between economic openness and economic growth: Issue of openness measurement. *Applied Economics: Systematic Research*, 12(2), 13-28.

Eren, B. M., Taspinar, N., & Gokmenoglu, K. K. (2019). The impact of financial development and economic growth on renewable energy consumption: Empirical analysis of India. *Science of the Total Environment*, *663*, 189-197.

Etokakpan, M. U., Adedoyin, F. F., Vedat, Y., & Bekun, F. V. (2020). Does globalization in Turkey induce increased energy consumption: Insights into its environmental pros and cons. *Environmental Science and Pollution Research*, *27*, 26125-26140.

Fareed, Z., Salem, S., Adebayo, T. S., Pata, U. K., & Shahzad, F. (2021). Role of export diversification and renewable energy on the load capacity factor in Indonesia: A Fourier quantile causality approach. *Frontiers in Environmental Science*, *434*.

Feng, G. F., & Zheng, M. (2022). Economic policy uncertainty and renewable energy innovation: International evidence. *Innovation and Green Development*, *1*(2), 100010.

Gozgor, G., Mahalik, M. K., Demir, E., & Padhan, H. (2020). The impact of economic globalization on renewable energy in the OECD countries. *Energy Policy*, *139*, 111365.

Gozgor, G. (2016). Are shocks to renewable energy consumption permanent or transitory? An empirical investigation for Brazil, China, and India. *Renewable and Sustainable Energy Reviews*, *66*, 913-919.

Guo, P., Zhu, H., & You, W. (2018). Asymmetric dependence between economic policy uncertainty and stock market returns in G7 and BRIC: A quantile regression approach. *Finance Research Letters*, *25*, 251-258.

He, A., Xue, Q., Zhao, R., & Wang, D. (2021). Renewable energy technological innovation, market forces, and carbon emission efficiency. *Science of the Total Environment*, *796*, 148908.

Hsiao, C., & Tahmiscioglu, A. K. (2008). Estimation of dynamic panel data models with both individual and time-specific effects. *Journal of Statistical Planning and Inference*, *138*(9), 2698-2721.

Ibrahiem, D. M., & Hanafy, S. A. (2020). Dynamic linkages amongst ecological footprints, fossil fuel energy consumption and globalization: An empirical analysis. *Management of Environmental Quality: An International Journal*, *31*(6), 1549-1568.

International Energy Agency. (2018). *World Energy Outlook 2018*. Retrieved from https://www.iea.org/weo/china/.

Ji, Q., & Zhang, D. (2019). How much does financial development contribute to renewable energy growth and upgrading of energy structure in China? *Energy Policy*, *128*, 114-124.

Joof, F., Samour, A., Ali, M., Tursoy, T., Haseeb, M., Hossain, M. E., & Kamal, M. (2023). Symmetric and asymmetric effects of gold, and oil price on environment: The role of clean energy in China. *Resources Policy*, *81*, 103443.

Karaaslan, A., & Çamkaya, S. (2022). The relationship between CO2 emissions, economic growth, health expenditure, and renewable and non-renewable energy consumption: Empirical evidence from Turkey. *Renewable Energy*, *190*, 457-466.

Kihombo, S., Ahmed, Z., Chen, S., Adebayo, T. S., & Kirikkaleli, D. (2021). Linking financial development, economic growth, and ecological footprint: What is the role of technological innovation? *Environmental*

Science and Pollution Research, *28*(43), 61235-61245.

Kim, J., & Park, K. (2016). Financial development and deployment of renewable energy technologies. *Energy Economics*, *59*, 238-250.

Kirikkaleli, D., & Adebayo, T. S. (2021). Do renewable energy consumption and financial development matter for environmental sustainability? New global evidence. *Sustainable Development*, *29*(4), 583-594.

Koengkan, M., Poveda, Y. E., & Fuinhas, J. A. (2020). Globalisation as a motor of renewable energy development in Latin America countries. *GeoJournal*, *85*, 1591-1602.

Koengkan, M., Fuinhas, J. A., & Santiago, R. (2020). The relationship between CO2 emissions, renewable and non-renewable energy consumption, economic growth, and urbanisation in the Southern Common Market. *Journal of Environmental Economics and Policy*, *9*(4), 383-401.

Ko, J. H., & Lee, C. M. (2015). International economic policy uncertainty and stock prices: Wavelet approach. *Economics Letters*, *134*, 118-122.

Lahiani, A., Mefteh-Wali, S., Shahbaz, M., & Vo, X. V. (2021). Does financial development influence renewable energy consumption to achieve carbon neutrality in the USA? *Energy Policy*, *158*, 112524.

Lei, W., Liu, L., Hafeez, M., & Sohail, S. (2021). Do economic policy uncertainty and financial development influence the renewable energy consumption levels in China? *Environmental Science and Pollution Research*, 1-10.

Lensink, R. (2001). Financial development, uncertainty and economic growth. *De Economist*, *149*(3), 299-312.

Li, M., Ahmad, M., Fareed, Z., Hassan, T., & Kirikkaleli, D. (2021). Role of trade openness, export diversification, and renewable electricity output in realizing carbon neutrality dream of China. *Journal of Environmental Management*, *297*, 113419.

Lin, B., Omoju, O. E., & Okonkwo, J. U. (2016). Factors influencing renewable electricity consumption in China. *Renewable and Sustainable Energy Reviews*, *55*, 687-696.

Liu, R., He, L., Liang, X., Yang, X., & Xia, Y. (2020). Is there any difference in the impact of economic policy uncertainty on the investment of traditional and renewable energy enterprises? – A comparative study based on regulatory effects. *Journal of Cleaner Production*, *255*, 120102.

Mukhtarov, S., Humbatova, S., Hajiyev, N. G. O., & Aliyev, S. (2020). The financial development-renewable energy consumption nexus in the case of Azerbaijan. *Energies*, *13*(23), 6265.

Musah, M., Kong, Y., Mensah, I. A., Antwi, S. K., & Donkor, M. (2020). The link between carbon emissions, renewable energy consumption, and economic growth: A heterogeneous panel evidence from West Africa. *Environmental Science and Pollution Research*, *27*, 28867-28889.

Magazzino, C., Toma, P., Fusco, G., Valente, D., & Petrosillo, I. (2022). Renewable energy consumption, environmental degradation and economic growth: The greener the richer? *Ecological Indicators*, *139*, 108912.

Magazzino, C., Mele, M., & Morelli, G. (2021). The relationship between renewable energy and economic growth in a time of COVID-19: A machine learning experiment on the Brazilian economy. *Sustainability*, *13*(3), 1285.

Magazzino, C. (2017). Renewable energy consumption-economic growth nexus in Italy. *International Journal of Energy Economics and Policy*, *7*(6), 119-127.

Masini, A., & Menichetti, E. (2013). Investment decisions in the renewable energy sector: An analysis of non-financial drivers. *Technological Forecasting and Social Change*, *80*(3), 510-524.

Meo, S. A., Al-Khlaiwi, T., Aljofan, Z. F., Alanazi, A. I., & Meo, A. S. (2022). Public perceptions of the emerging human monkeypox disease and vaccination in Riyadh, Saudi Arabia: A cross-sectional study. *Vaccines*, *10*(9), 1534.

Mukhtarov, S., Mikayilov, J. I., Maharramov, S., Aliyev, J., & Suleymanov, E. (2022). Higher oil prices, are they good or bad for renewable energy consumption: The case of Iran? *Renewable Energy*, *186*, 411-419.

Moradbeigi, M., & Law, S. H. (2017). The role of financial development in the oil-growth nexus. *Resources Policy*, *53*, 164-172

Nazir, M. R., Nazir, M. I., Hashmi, S. H., & Fareed, Z. (2018). Financial development, income, trade, and urbanization on CO2 emissions: New evidence from Kyoto annex countries. *Journal on Innovation and Sustainability RISUS*, *9*(3), 17-37.

Nguea, S. M. (2020). Openness and government size in Sub-Saharan African countries. *Economics Bulletin*, *40*(4), 2669-2676.

Ojekemi, O. S., Ağa, M., & Magazzino, C. (2023). Towards achieving sustainability in the BRICS economies: The role of renewable energy consumption and economic risk. *Energies*, *16*(14), 5287.

Padhan, H., Padhang, P. C., Tiwari, A. K., Ahmed, R., & Hammoudeh, S. (2020). Renewable energy consumption and robust globalization (s) in OECD countries: Do oil, carbon emissions and economic activity matter? *Energy Strategy Reviews*, *32*, 100535.

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of econometrics*, *142*(1), 50-93

Pham, L. (2019). Does financial development matter for innovation in renewable energy? *Applied Economics Letters*, *26*(21), 1756-1761.

Ulucak, R., & Khan, S. U. D. (2020). Determinants of the ecological footprint: Role of renewable energy, natural resources, and urbanization. *Sustainable Cities and Society*, *54*, 101996.

Raghutla, C. (2019). *An empirical investigation of financial development on sustainable economic development and environmental quality in BRICS countries* (Doctoral dissertation [PhD thesis, Central University of Tamil Nadu, India]. Retrieved from https://shodhganga. inflibnet. ac. in/ handle/10603/267810.

Raghutla, C., Shahbaz, M., Chittedi, K. R., & Jiao, Z. (2021). Financing clean energy projects: New empirical evidence from major investment countries. *Renewable Energy*, *169*, 231-241.

Raza, S. A., Shah, N., Qureshi, M. A., Qaiser, S., Ali, R., & Ahmed, F. (2020). Non-linear threshold effect of financial development on renewable energy consumption: Evidence from panel smooth transition regression approach. *Environmental Science and Pollution Research*, *27*, 32034-32047.

Razmi, S. F., Bajgiran, B. R., Behname, M., Salari, T. E., & Razmi, S. M. J. (2020). The relationship of renewable energy consumption to stock market development and economic growth in Iran. *Renewable Energy*, *145*, 2019-2024.

Rehman, M. A., Fareed, Z., & Shahzad, F. (2022). When would the dark clouds of financial inclusion be over, and the environment becomes clean? The role of national governance. *Environmental Science and Pollution Research*, *29*(19), 27651-27663.

Sadorsky, P. (2009). Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. *Energy Economics*, *31*(3), 456-462.

Sarkodie, S. A., & Owusu, P. A. (2021). Impact of COVID-19 pandemic on waste management. *Environment, Development and Sustainability*, *23*, 7951-7960.

Shafiullah, M., Miah, M. D., Alam, M. S., & Atif, M. (2021). Does economic policy uncertainty affect renewable energy consumption? *Renewable Energy*, *179*, 1500-1521.

Shan, S., Ahmad, M., Tan, Z., Adebayo, T. S., Li, R. Y. M., & Kirikkaleli, D. (2021). The role of energy prices and non-linear fiscal decentralization in limiting carbon emissions: Tracking environmental sustainability. *Energy*, *234*, 121243.

Sohail, M. T., Xiuyuan, Y., Usman, A., Majeed, M. T., & Ullah, S. (2021). Renewable energy and non-renewable energy consumption: assessing the asymmetric role of monetary policy uncertainty in energy consumption. *Environmental Science and Pollution Research*, *28*, 31575-31584.

Sulong, Z., & Farouq, I. S. (2023). The role of FDI uncertainty on financial development: evidence from panel data. *International Journal of Business Innovation and Research*, *30*(3), 352-369.

Su, C. W., Khan, K., Umar, M., & Chang, T. (2022). Renewable energy in prism of technological innovation and economic uncertainty. *Renewable Energy*, *189*, 467-478.

Tamazian, A., Chousa, J. P., & Vadlamannati, K. C. (2009). Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. *Energy policy*, *37*(1), 246-253.

Wang, B., Yan, C., Iqbal, N., Fareed, Z., & Arslan, A. (2022). Impact of human capital and financial globalization on environmental degradation in OBOR countries: Critical role of national cultural orientations. *Environmental Science and Pollution Research*, *29*(25), 37327-37343.

Wang, H., & Ye, Z. (2016, November). Renewable energy-aware demand response for distributed data centers in smart grid. In *2016 IEEE green energy and systems conference (IGSEC)* (pp. 1-8). IEEE.

Wei, J., Alfajaro, M. M., DeWeirdt, P. C., Hanna, R. E., Lu-Culligan, W. J., Cai, W. L., & Wilen, C. B. (2021). Genome-wide CRISPR screens reveal host factors critical for SARS-CoV-2 infection. *Cell*, *184*(1), 76-91.

Xu, D., Salem, S., Awosusi, A. A., Abdurakhmanova, G., Altuntaş, M., Oluwajana, D., & Ojekemi, O. (2023). Load capacity factor and financial globalization in Brazil: The role of renewable energy and urbanization. *Financial and Trade Globalization, Greener Technologies and Energy Transition*, *16648714*, 47.

Yi, S., Raghutla, C., Chittedi, K. R., & Fareed, Z. (2023). How economic policy uncertainty and financial development contribute to renewable energy consumption? The importance of economic globalization. *Renewable Energy*, *202*, 1357-1367.

Zhang, Y., Qamruzzaman, M., Karim, S., & Jahan, I. (2021). Nexus between economic policy uncertainty and renewable energy consumption in BRIC nations: The mediating role of foreign direct investment and financial development. *Energies*, *14*(15), 4687.