energies

Article

Determining If Oil Prices Significantly Affect Renewable Energy Investment in African Countries with Energy Security Concerns

Ishaya Tambari * and Pierre Failler

Centre for Blue Governance, Department of Economics and Finance, University of Portsmouth, Portsmouth P01 3DE, UK; pierre.failler@port.ac.uk

* Correspondence: ishaya.tambari@myport.ac.uk

Received: 30 August 2020; Accepted: 7 December 2020; Published: 21 December 2020

Abstract: As concerns regarding the adverse impacts of energy production and consumption on the environment grow, countries across the world are now charged with developing effective strategies that provide energy security and protect the environment. This means that efforts to generate significant investments and business opportunities to boost the growth of renewable energy need to increase rapidly. However, there are limited studies on what will facilitate the increase of renewable energy investment in Africa. The main factor considered in this study relates to the sensitivity to changes in oil prices, gross domestic product (GDP), interest rate and oil price volatility's impact on the renewable energy investment (REI) in countries with energy security concerns and if there is any significant influence from oil price shocks. With the help of an unrestricted vector retrogressive model and an annual panel data approach that covers the period 1990–2018, this paper examines the link between renewable energy investment and three macroeconomic variables: oil prices, GDP growth-adjusted interest rates and oil price volatility. The results indicate that REI exhibited immediate positive responses to oil shocks. However, renewable energy investment continued to fluctuate negatively in response to GDP. The results also show that the REI responded positively to interest rates in Africa and it exhibited immediate negative responses to oil price volatility but became positive after the second period.

Keywords: renewable energy investment (REI); oil price; gross domestic product (GDP); vector autoregression (VAR); renewable energy

1. Introduction

Africa has an abundance of energy resources. The region is energy self-sufficient and a net exporter of crude oil, natural gas and coal. Nigeria, Angola and Algeria lead the region in oil reserves and production with over 60% of the continent's oil production in 2017 (International Energy Agency, 2019). Algeria, Nigeria, Egypt and Ethiopia are also among the region's leaders in natural gas reserves and production, while South Africa is the fourth-largest coal exporter in the world, producing 92.5% of African coal in 2017 (International Energy Agency, 2019).

Much of Africa still depends on fossil fuels and renewable energy sources in the form of rich sunshine for solar power, water and river bodies for hydropower, and there is potential for wind energy which is yet to be tapped [1,2]. Out of 1750 terawatt-hours (TWh) of hydropower in Africa, only around 5% has been tapped [3,4]. Following the adoption of the 2015 Paris Climate Agreement in December 2016, increasing renewable energy production has now become a priority for achieving sustainable development and energy security [5]. Renewable energy technologies (RETs) have been identified as one of the best technologies to decarbonise the global electricity supply system [6–9].

This entails that the investment into RETs needs to heighten instantly, but it is less apparent what will stimulate this growth. The main component analyzed here pertains to whether the oil price considerably affects the investment in and production of renewable energy in developing countries. Oil price fluctuation is one of the major reasons most countries are finding renewable energy more attractive for the potential to reduce the overdependence on oil. However, reducing this reliance has been a major concern for most countries, especially due to the decline in oil price experienced since the 20 June 2014 to the current date, which has been having an adverse effect on economic growth, particularly in the crude oil-exporting countries in Africa. For instance, oil exporters in the region are heavily dependent on oil revenues to support energy infrastructure development. The World Bank (2015) observed that oil revenue contributes to about 50% of output growth and over 70% of export earnings. There is no unanimity on the impacts that oil prices have on renewable energy investment, as it depends on the extent to which oil price changes encourage investment in renewable energy in Africa. This comes with the challenges of diversified energy bases and shortages of electricity supply despite the quantity of renewable energy sources in the region.

The purpose of this paper is to analyse the link between oil price, gross domestic product (GDP), adjusted interest rate and renewable energy investment and to determine the policy implications thereof. The study extends the recent research on linkages between oil price and renewable energy investment [4,10–12] for the case study of Africa. Specifically, these studies show the underlying reasons these variables should be related, which are: (1) renewable energy policies appear to consider a country's economic dimensions (e.g. [13,14]), which by looking at the relationship between GDP and renewable energy investment, this paper will validate or invalidate this; (2) the price of oil and renewable energy investment appear to be positively related (e.g. [13]), which this study intends to establish the case for the six African countries involved; and (3) there appears to be a positive correlation between an adjusted interest rate and renewable energy investment (e.g. [13,15]) which will be confirmed herein. Since these relationships are true in many countries such as in the U.S. [13], it would be interesting to know whether the same trend exists in African countries and could, therefore, enable policy determinations directed at renewable energy in these countries.

This research further aims to investigate the investment uncertainty and the sensitivity to changes in oil prices, GDP, interest rate and oil price volatility impact on renewable energy investment and if there is any significant influence from oil price shocks. In addition, it aims to develop recommendations for improving energy policies that will enhance the achievement of the renewable energy targets under the Nationally Determined Contributions (NDCs) in the largest net crude oil, natural gas and coal dependents and in the biggest economies in the five regions of Africa, namely Nigeria (West), Algeria and Egypt (North), Ethiopia (East and Central Africa), and Angola and South Africa (Southern). The choice of the case study was in relation to the previous related study of Olanrewaju et al. [4]. In addition, this study used six countries instead of five as indicated by Olanrewaju et al. [4]; furthermore, two countries were chosen from North Africa and southern Africa as a result of the level of fossil fuel production. Ethiopia represents two regions, East and Central Africa, based on a related study by the World Bank which stated that Ethiopia has the largest economy in East and Central Africa [16]. Furthermore, the fossil fuel production and renewable energy consumption in the six countries combined represent over 70% and 60% of the whole of Africa, respectively [4,17]. The paper employs an unrestricted vector autoregression (VAR) model and panel approach using data from 1990–2018. Most of the techniques were not previously considered in this area of the literature before.

The paper is organized as follows: Section 2 covers the literature review; Section 3 describes the methodology describing the data used in the paper and the empirical models estimated; results are presented and discussed in Section 4, and conclusions and policy recommendations are made in Section 5.

2. Literature Review

The increasing role of renewable energy in power sources is indicated in the global drive for their integration. The intermittent character of renewable energy sources allows them to introduce operational uncertainty to system functioning [18]. Ergun et al. suggested that a rise in foreign direct investment is linked to higher renewable energy integration [19]. Investors are confronted with a range of uncertainties when making an enterprise decision in renewable energy. This consequently has huge relevance to the advancement of renewable energy in assessing the risks and making the best investment decisions [20].

Deciphering the relationship between oil prices and renewable energy stock prices can aid in the decision-making pursuits of policymakers and investors [21]. Multiple studies investigated the effects of oil prices on renewable energy financial performance [22–25], however, these studies set aside the possibly important impact of oil price uncertainty on renewable energy, specifically in terms of financial performance. Using a VAR analysis, Kumar et al. found that oil price affects the stock prices of renewable energy companies [22]. Sadorsky showed a higher correlation between the stock prices of renewable energy firms and technology firms than oil prices [23]. On the other hand, Reboredo et al. in 2017 revealed a short run weak dependence between oil and alternative energy returns, which slowly built up in the long run [25]. Quite the reverse, they reported strong evidence of non-linear causality from alternative energy indices to oil prices at various time periods and varied evidence of causality from oil to alternative energy prices.

Conversely, in 2020, Zhao used the VAR model to examine the impact of oil price shocks and policy uncertainty on the stock returns of renewable energy firms [26]. His findings revealed that oil price shocks positively affected the returns of renewable energy firms, whilst policy uncertainly shocks negatively affected it. Furthermore, the impact of oil shocks on the renewable energy stock returns increased when policy uncertainty was added as an endogenous factor to the VAR model. Similarly, in their investigation of the impact of oil price shocks on renewable energy and technology firms, Kyritsis and Serletis used the VAR model and monthly data covering the period 1983–2016 [27]. Their findings suggested no statistically significant effect made by oil price uncertainty on stock returns. They also found a symmetrical relationship between oil prices and stock returns, which were in contrast to Zhao's [26] findings. On the other hand, studying the link between oil and renewable energy stock prices, Dominioni et al. found that oil has always been in a predator–prey interaction with wind but not with solar, with which it has had a mutualistic relationship since 2012 [21].

Moreover, Eregha and Mesagan found that oil price and energy consumption in African countries substantially increased output growth and reduced inflation rates [28]. This led them to propose that African countries should boost their power generation and local crude oil generation at affordable rates in order to bolster energy use and minimize adverse exogenous oil price shocks on the macroeconomy. Alternatively, analyzing the causal relationship between renewable energy consumption, oil prices and economic activity using Granger causality, Troster et al. found results that are supportive of unidirectional causality from changes in oil prices to economic growth at the far end of the distribution quantiles, as well as evidence of dependence from variations in oil prices to variations in renewable energy use at the lower tail [29]. Overall, Troster et al. signified a need for government policies that focus on the development of renewable energy markets to boost energy efficiency.

Studying the effects of the drop in the prices of oil on renewable energy, Khan et al. compared declines in oil prices and showed that the recent drop in oil prices did not create major impacts on the renewable energy sector [30]. Whilst continuing low oil prices may pose a threat to renewable energy, this can be potentially counterweighed by climate policies, such as a low carbon investment pursuit. On the other hand, results in the study of Miketa and Merven revealed that if the cost of renewable energy in West African countries will continue to drop and the prices of crude oil will continue to increase, the share of renewable energy in these counties could increase [31]. This picture implies that by 2030, almost half of the envisioned capability additions would be renewables. Both of these studies of suggest that volatility in oil price does not negatively affect renewable energy investment [30,31].

Moreover, regression results in the study of Kebede et al. showed that whilst an inverse relationship exists between energy demand and oil price and industrial growth, a positive relationship exists between energy demand and GDP in sub-Saharan Africa [13]. They also stressed that regional differences exist in commercial energy use and GDP growth. These findings denote a need for diversification of energy sources in these countries, as well as an introduction of energy-efficient instruments to improve the GDP growth rate. In the same vein, Aldarraji and Bakir found that renewable energy has a positive impact on economic growth, indicating that countries should invest in renewable energy and slowly minimize their reliance on traditional energy and that all obstacles to developing renewable energy should be eliminated [32]. Likewise, key findings in the study of Singh et al. revealed that renewable energy production is positively and statistically associated with economic growth in developed and developing countries, although this was higher for developing countries than developed ones [33]. Marinas and Dinu also found that economic growth and renewable energy consumption are bi-directionally related [34]. On the other hand, Maji et al. found that renewable energy can decelerate economic growth by reducing productivity when unclean and inefficient energy sources are consumed [35].

By exploring financial de-risking to unravel renewable energy prospects in Africa, Sweerts et al. highlighted that low GDP per capita and the high weighted average cost of capital characterize African countries [36]. These countries tend to progress towards improved country risk evaluation by international credit rating agencies, which is expected to result in higher foreign investments at increasingly lower interest rates. Hafner et al. pointed out that international investors are prevented by combined political risks, commercial risks and inadequate energy infrastructure from increasing investments into sub-Saharan Africa's energy sector [37]. Indeed, given an unsafe business environment, equity investors will be required to accept higher interest rates from banks and returns on investment [38]. Klagge and Nweke-Eze clarified that with energy transitions and economies of scale progressing, renewable energy production begins to involve wide-ranging operations [39]. This shift takes place in the course of important changes in the financial structures of renewable energy ventures, including connections and interdependencies of international and local investors and regulations. As they increase in size and maturity, renewable energy ventures are also being carried to capital markets and are bound by financialization.

In terms of access to financing renewable energy, only a limited share of domestic loans is available in many African countries. Even in cases where these loans are available, high interest rates are being offered to these countries. The poor credit ratings of many African countries hinder private investors from having access to international financial organizations since African institutional investors are not attracted to financial instruments of energy projects [40]. Schwerhoff and Sy emphasized that renewable energy facilities are expensive to begin with, however, the energy sources are free or involve only a minor cost [41]. Deciding on the most efficient type of investment is thus determined by the interest rate faced by the investor; in Africa, this is typically the government. However, borrowing would be the financing option for implementing large-scale renewable energy projects. Considering the difficulty in financing huge infrastructure projects in the region, the cheapest form of energy generation would, in most cases, be the option for investors if there is no available assistance from international financing agencies. Very low interest rates can be possibly accessed and passed on to investors by regional development banks [41]. On a parallel note, Baker pointed out that liberalizing the interest rates and privatizing state-owned banks are key factors associated with financing renewable energy [42].

Similarly, Egli et al. emphasized that renewable energy technologies are often costly, and their financing conditions are usually not understood [43]. They identified macroeconomic conditions such as general interest rates and concluded that existing studies may overrate technological learning. They also found that increased general interest rates may lead to increased levelized costs of renewable energy, eliminating doubts on the efficiency of plans to discontinue policy support.

Deciding on the most efficient type of investment is determined by the interest rate faced by the investor; in Africa, this is typically the government. However, borrowing would be the financing option for implementing large-scale renewable energy projects. Considering the difficulty in financing huge infrastructure projects in the region, the cheapest form of energy generation would in most cases be the option for investors if no available assistance from international financing agencies is provided. In addition, very low interest rates can be possibly accessed and passed on to investors by regional development banks [41]. Kim et al. pointed out that traditional approaches for economic assessment are not enough to support investment-specific decision making in renewable energy [44].

Klagge and Nweke-Eze clarified that with energy transitions and economies of scale progressing, renewable energy production begins to involve wide-ranging operations [39]. This shift takes place in the course of important changes in the financial structures of renewable energy ventures, including connections and interdependencies of international and local investors and regulations. As they increase in size and maturity, renewable energy ventures are also being carried to capital markets and are bound by financialization. Klagge and Nweke-Eze further argued that owing to multifaceted risk structure, domestically led and institutionally led public investment and support will continue to function as the key to facilitate such ventures. Bhattacharya and Kojima claimed that investors would benefit from the high competitiveness of the renewable energy market by minimizing the risks associated with energy supply instead of focusing on the cost, thereby increasing renewable energy supply in the market [45].

It should be noted that a large part of the broad empirical literature on the uncertainty–investment relationship is focused on natural resource industries. Moel and Tufano found that real options models are viable for explaining resource-related decisions by integrating the impact of uncertainty, however, they argued that these models failed to include aspects of firm-level decision making [46]. In a model developed by Sarkar, he showed that an increase in uncertainty does not automatically create an inhibiting effect on investment in renewable energy [47]. Favero et al. made an empirical investigation of the way oil price and oil price uncertainty influences the decision process on the UK Continental Shelf and revealed that both serve as important determining factors in the development decision process [48].

Furthermore, in his valuation of alternative energy investment under uncertainty, Li [49] reported that alternative energy producers avoid risks when confronted with uncertain future policy environment, as mirrored in delays of investment plans. In contrast, for a risk-neutral, price-tolerant power producer, it is more effective to use emission trading than carbon tax since emission trading can effectively induce speedy alternative energy investment. Bolton et al. argued that major energy and infrastructure policies are aimed at enabling alternative technologies investable through uncertainty reduction, investment risk management and reposition of actors within the energy socio-technical platform [50]. On the other hand, Komendantova et al. identified three risks in renewable energy investment in North Africa: political risk, regulatory risk and force majeure (e.g., terrorism), which are of high concern [51]. This indicates that focusing on establishing the capabilities of countries in North Africa to carry out effective regulations could be a first step in promoting collaboration on renewable energy adoption. Investigating the drivers of renewable energy and estimating the demand for renewable energy in Africa, Ackah and Kizys pointed out that policies should focus on encouraging the use of commercial renewable energy sources in attracting the needed investments [52].

Furthermore, finding out whether oil price uncertainty impacts the investment of renewable energy companies, Cao et al. found that oil price uncertainty negatively and significantly affects investment and that it affects smaller firms rather than larger ones [53]. This result demonstrates that the link between investment and investment opportunities can be enhanced by oil price volatility, specifically for small-sized firms which are more likely to encounter financing constraints. Moreover, debt capital ratio and other firm-characteristic variables are essential in determining renewable energy investment behavior. Qadan and Idilbi-Bayas noted that oil price volatility is not only governed by real economic shocks, but also by shocks arising from the economic uncertainty and investors' risk level in the equity market [54].

By contrast, Fleten et al. studied renewable energy generation under uncertainty and found that capacity selection can be based on the existing price and volatility of the market [55]. They stressed that with low price volatility, price intervals for investment can be more than one for a variety of units. On the other hand, with high price volatility, the value of investment opportunities can be increased, which makes it more appealing to defer investment until more gainful profits occur.

Conversely, Hafner et al. pointed out that international investors are prevented from increasing investments into sub-Saharan Africa's energy sector by combined political risks, commercial risks and inadequate energy infrastructure [37]. Indeed, given an unsafe business environment, equity investors will be required to accept higher interest rates from banks and returns on investment [38]. Joskow and Tirole [56] identified various kinds of political risks as key barriers for investment in renewable energy in North Africa from regulatory barriers and uncertainty concerning future policies to terrorism and sabotage risks [57]. These risks are classified into two basic types: regulatory risks, which are caused by government actions, and security risks, which are caused by the actions of non-government groups [51]. According to Fabrizio, the firms' investment decisions are impacted by possible uncertainty in the regulatory system [58]. In Ghana, regulatory uncertainties are one of the main constraints to investment in renewables [59]. Exploring the patterns of investment in renewables in the United States, Fabrizio found that firms made fewer investments in new assets in places that legislated and repealed laws for the restructuring of the energy sector, which suggests that a perception of regulatory uncertainty minimizes new investment [58]. Barradale also claimed that decreasing regulatory uncertainty is an important element to a sound policy for renewable energy investment [60].

Similar to this was the study by Eryilmaz and Homans who focused on examining the effects of policy-related uncertainties on the investment decisions of renewable energy firms, focusing on the U.S. context [61]. Their findings demonstrated that higher prices of renewable energy credits are required for investors to make an investment without a tax credit policy. These findings provide an understanding of the manner in which policy uncertainty impacts the profitability threshold which investors need to engage in renewable energy endeavours. Burns mentioned that policy uncertainty reflects a considerable risk for investors and is an important consideration for evaluating the profitability of investment decisions [62]. Several studies support the suggestion that greater risk embodies renewable energy investments as perceived by investors and this is caused by the risk in policy uncertainty, however, this proposition is not supported by any empirical evidence [61].

On the other hand, examining the investment decisions of oil firms that operate in the Norwegian Continental Shelf, Berntsen et al. found that oil price, size of the oil reserves and geological variables serve as the most essential elements that influence investment decisions [63]. They also noted the insignificant impact of oil price volatility. Since investment decisions have an important role to play in oil companies and since they are fashioned repetitively, these firms can prospectively provide time and resources into investment decisions [64]. Horn et al. validated this as they found that decision makers in the energy sector often use advanced systems for appraising investment [65]. As far as Bøe et al. are concerned, there are no studies analyzing the effects of financial development on oil investment and there are only two, which are based on micro-level data, which examine the influence of political stability on oil investments [64].

Narayan and Ponnambalam emphasized the importance of minimizing risk in the investment caused by the uncertain nature of renewable energy sources, as well as reducing the expected investment cost [66]. Venetsanos et al. noted the importance of a real options approach in wind energy investment projects under uncertainty [67]. Murto examined the impact of uncertainty on technology and revenue in renewables, showing the interaction between them [68]. Aiming to focus on the processes surrounding strategic options for investment in renewables and how energy policy influences them, Wustennhagen and Menichetti explored portfolio effects and risk-return viewpoints to explain investment decisions and pointed out that investors in renewable energy require the dissection of policies [69].

Similarly, Bøe et al. studied the effect of political risks and financial growth on investment in the oil industry and found that it takes a shorter expected time for investment in countries with political stability, strong property rights protection and more developed financial methods [64]. At the firm level, they found a shorter expected time for investment for firms with a higher valuation and lower debts. Furthermore, firms tend to invest in countries where they recently made an investment and tend not to invest in countries where their competitors recently made an investment. Liu and Zeng found that policy risk is a key element that affects investments in the initial phase [20]. While both technology risk and policy risk decrease slowly, market risks become the key uncertainty impacting investment at the mature stage. By exploring financial de-risking to unravel renewable energy prospects in Africa, Sweerts et al. highlighted that low GDP per capita and a high weighted average cost of capital characterize African countries [36]. These countries tend to progress towards improved country risk evaluation by international credit rating agencies, which are expected to result in higher foreign investments at increasingly lower interest rates. In their study of huge renewable projects in sub-Saharan Africa, Hafner et al. pointed out that the development of these projects places both developers and institutions at the forefront of the need to manage investment risks [37]. Using South Africa as a case study, Pegels identified cost structures and risk structures as the main determinants of investment planning for renewable energy [70].

Furthermore, Sendstad and Chronopoulos stressed that while innovation and support strategies are amongst the key forces driving investment in renewables, significant uncertainty is embodied in them [71]. In their study on investment decisions in energy generation technologies under uncertainty, Gugler et al. found that asset-related uncertainties deter investment in traditional technologies while industry uncertainties even boost investment [72]. Considering that renewable energy takes the place of peak-load generation technologies and that investment incentives eventually decrease, underinvestment may occur in the long run. Gugler et al. noted that during the period of high renewable generation, there is a drop in the residual demand for traditional production, reducing their capacity utilization and profitability which may hold back extensive investments [72]. An understanding of the factors that determine electricity production-capacity investment gives importance beyond the academic field since electricity is necessary for energy to transition to a decarbonized method to respond to climate change. Kinias et al. took into account the time factor for investment and the price of electricity as they created an investment analysis model, aiming to search for the optimal investment scheme in a liberalized global energy market with the uncertain price of electricity and investment [73].

Most of the literature relating to investment uncertainty, renewable energy investment and macroeconomics in Africa has focused on the modelling determinants of renewable energy consumption [4,74], the dynamic relationship between renewable energy and economic growth [75] and policies for the promotion of commercial-scale renewable energy investment [59]. To date, renewable energy investment has not been able to compete with fossil fuels, and renewable energy varies from location to location [12]. To adequately assess the investment uncertainty and the roles and benefits of increased penetration of renewable energy on the African continent for improved energy access, it is necessary to investigate the sensitivity in changes in the major substitute (oil), the macroeconomic variables (output and interest rate) and investment uncertainty (oil price volatility). A brief review of other relevant literature, which investigates renewable energy consumption and production and macroeconomic variables, is presented in Table 1.

Table 1. Review of the recent literature on fossil fuel price and renewable energy.

Study	Methodology	Time Period	Countries	Remark
[10]	Panel cointegration and error correction models (ECM)	1980–2010	25 OECD countries	There is a long run statistically significant relationship between renewable energy and oil prices
[10]	Non-linear smooth transition panel vector ECM	1980–2010	7 Central American countries	A positive and statistically significant relationship between renewable energy and oil prices
[76]	Panel cointegration and error correction modelling	1980–2010	11 South American Countries	There is a long-run positive statistically significant relationship between renewable energy consumption, GDP and oil prices
[77]	Model for the quantitative panel regression	2000–2011	OECD	Policy and market instrument such as FIT, GHG, RPS and long-term strategic planning measures directly impact the risk and return structure of renewable energy projects and could further strengthen the context for renewable energy investment
[78]	VAR model	1996–2014	China	GDP and interest rates respond significantly to oil price
[11]	Case study approach		Latin America and the Caribbean	Oil price plunges pose the risk of disrupting REI from the private sector to the extent that they become less and insufficiently profitable. The private sector is motivated by a sufficient market-based return from investment while accounting for any financial support a specific country may be providing to the sector
[79]	Case study approach		6 GCC countries	Failing oil prices affect renewable energy projects due to decreasing oil revenue and government subsidies for oil and other fossil fuels which negatively affects the development and support of renewables. The implementation of proper regulation proper policies as well as fiscal incentives are the main factors that will enhance the renewable energy transition in GCC countries
[80]	Dynamic general equilibrium (DGE) model	1995–2014	Kingdom of Saudi Arabia (KSA)	There is a positive relation between oil price and renewable energy in KSA, and the 5% increase of renewable energy for electricity generation in KSA by 2030 would bring a positive impact in output and household welfare

Table 1. *Cont.*

Study	Methodology	Time Period	Countries	Remark
[29]		1989–2016	The U.S.	Negative shocks in oil prices affect the consumption of renewable energy resources. The authors observed that the development of renewable energy markets in the U.S. contribute to reducing their dependence on oil, allowing the U.S. economy to become less sensitive to positive shocks in oil prices
[59]	Green Investment Diagnostics		Ghana and Kenya	Macroeconomic imbalance, policy uncertainties, lack of and costly domestic finance, lack of network infrastructure and governance and social acceptance problems are the major obstacles for achieving increased renewable energy for electricity generation
[27]	Bivariate structural VAR model and GARCH-in Mean model	1983–2016	WilderHill Clean Energy Index (ECO), WilderHill New Energy Global Innovation Index (NEX), and S&P Global Clean Energy Index (SPGCE)	Oil price volatility has no statistically significant effect on stock returns and that the relationship between oil prices and stock returns is symmetric
[4]	Fixed and random effects models and Hausman test	1990–2015	5 African countries	Oil rents have a negative relationship with renewable energy consumption in Africa. A decrease in oil rents will lead to an increase in renewable energy consumption African countries, need to diversify fossil fuels price risk and to support the cost of renewable energy
[81]	The error-correction model (VECM)	1986–2014	Tunisia	A bi-directional Granger causality between oil price, energy consumption and GDP

[1] Notes: FIT is feed-in tariffs, GHG is greenhouse emissions and RPS is renewable portfolio standards.

Currently, there are a lack of studies linking renewable energy investment to oil prices using data in the three Organization of Petroleum Exporting Countries (OPEC) members in Africa and the most populous and biggest economies in the five regions in Africa. No study investigates the sensitivity of changes in oil price, GDP growth, interest rate and oil price volatility in achieving the 2015 NDC target of renewable energy investments on the continent of Africa. The most closely related study is by Abid [81], which used VECM to investigate the dynamic causality relationships among the oil prices, GDP and energy consumption for Tunisia. In general, the previous literature on Africa has concentrated on renewable energy consumption and economic growth and the determinants of renewable energy consumption [4]. This study focuses on developing a better understanding of the roles and benefits of investment in renewable electricity generation, the macroeconomic impact, renewable energy and policy solutions in the transition towards achieving NDCs targets of power systems, and improved energy access for the six most populous and biggest economies in the five regions of Africa. In addition, this study seeks to determine the appropriate renewable energy policies to increase levels of access to electricity and to attract private investment.

3. Data and Methodological Framework

In econometric data analysis, the use of the panel data approach for analysis and to understand research problems has become increasingly important in recent studies, particularly when analyzing energy and macroeconomic data. Many macroeconomic problems are analyzed based on panel data, which is the same for forecasting the future economic conditions and understanding the relations between a set of possible related variables within an economic system or a specific market [82]. This research used an unrestricted VAR model panel data approach.

The purpose of using the VAR model is that the approach can be useful to see how a given asset, security or economic variable changes over time. It can also be used to examine how the changes associated with the chosen data point compare to shifts in other variables over the same time period. According to Gouriéroux, Monfort and Renne [83], the VAR model is a model first popularized by Sims in 1980 [84]. Nonetheless, the VAR is a regression framework and consequently is able to analyze many dependent variables [83]. Chiu, Mumtaz and Pinter have suggested that the VAR, as a multivariate model, has the capability to assess the reciprocal effects of two dependent variables and to analyze how the dynamics in their lags influence other variables and their individual lags [85]. They have noted that the VAR model treats the variables analyzed as endogenously dependent of one another and therefore does not restrict their structural connections.

3.1. Theoretical Framework

There is no specific theoretical model to elucidate the connection between oil price, renewable energy consumption, production and economic development when applying VAR model analysis. This research is based on Apergis and Payne [76], Sadorsky [82] and Shah et al. [12] in which output growth, interest rate and oil price have been considered as the factors that determine renewable energy investment. In addition, the Keynesian investment theory states that investment decisions depend on the relationship between the marginal efficiency of capital and interest rates. Moreover, for the energy sector, it is important to incorporate the price of the main substitute in the form of oil prices, giving a model consisting of oil prices, GDP and the interest rate as factors that can influence renewable energy investment [12].

3.2. Model Specification

Based on the theoretical framework in 3.1 above, this study utilizes an unrestricted VAR model to investigate the relationship between REI, oil prices, GDP, interest rate and oil price volatility across six oil-producing countries in Africa (Algeria, Angola, Egypt, Ethiopia, Nigeria, and South Africa) in the context of a panel VAR model for 1990–2018. The model incorporated oil prices, GDP growth (GDPg), adjusted interest rates, oil price volatility and the REI, which can be modelled as:

$$\text{REI} = \text{f (OIL, GDPg, INTR, OPVOL)} \quad (1)$$

$$\text{OIL} = \text{f (REI, GDPg, INTR, OPVOL)} \quad (2)$$

$$\text{GDPg} = \text{f (OIL, REI, INTR, OPVOL)} \quad (3)$$

$$\text{INTR} = \text{f (OIL, GDPg, REI, OPVOL)} \quad (4)$$

$$\text{OPVOL} = \text{f (OIL, GDPg, REI, OPVOL)} \quad (5)$$

This can be modelled in an econometrics format as:

$$\text{REI} = \beta 0 + \beta 1\text{REI}_{t-1} + \beta 2\text{OIL}_{t-1} + \beta 3\text{GDPg}_{t-1} + \beta 4\text{INTR}_{t-1} + \beta 5\text{OPVOL}_{t-1} + \mu \quad (6)$$

$$\text{OIL} = \beta 0 + \beta 1\text{OIL}_{t-1} + \beta 2\text{REI}_{t-1} + \beta 3\text{GDPg}_{t-1} + \beta 4\text{INTR}_{t-1} + \beta 5\text{OPVOL}_{t-1} + \mu \quad (7)$$

$$\text{GDPg} = \beta 0 + \beta 1\text{GDPg}_{t-1} + \beta 2\text{OIL}_{t-1} + \beta 3\text{REI}_{t-1} + \beta 4\text{INTR}_{t-1} + \beta 5\text{OPVOL}_{t-1} + \mu \quad (8)$$

$$\text{INTR} = \beta 0 + \beta 1\text{INTR}_{t-1} + \beta 2\text{GDPg}_{t-1} + \beta 3\text{OIL}_{t-1} + \beta 4\text{REI}_{t-1} + \beta 5\text{OPVOL}_{t-1} + \mu \quad (9)$$

$$\text{OPVOL} = \beta 0 + \beta 1\text{INTR}_{t-1} + \beta 2\text{GDPg}_{t-1} + \beta 3\text{OIL}_{t-1} + \beta 4\text{REI}_{t-1} + \beta 5\text{OPVOL}_{t-1} + \mu \quad (10)$$

where REI is renewable energy investment; OIL is real oil price; GDPg is output growth; INTR is interest rate and OPVOL is oil price volatility.

Sadorsky, in his findings, discovered a significant nexus between GDP and renewable energy source G7 countries between 1980 and 2005 [82]. Omri et al. also supported this in their model for developed and developing countries, which implies that economic growth is sufficient to prompt renewable energy growth [86]. Hence, a positive relationship between GDP per capita and REI is expected. Some authors have reported mixed results regarding the long-term relationship between economic development and REI with regards to the causality between economic growth and investment, with evidence of bi-causality (e.g. [22]). Economic growth can result in increased levels of investment through increased wealth and the capacity to allocate funding for infrastructure. The adjusted interest rate accounts for the monetary aspect of the economy, specifically the cost of borrowing, which is a key determinant of investment in the private sector [12]. Finally, the oil price was included in the model because it is a substitute for renewable energy, such that an increase in the oil price results in increased cost-effectiveness of investing in and producing renewable energy. The expectation is for oil-producing countries to demonstrate a close relationship between renewable energy and oil prices since energy security factors could lead to increased production of non-oil-based energy sources during times of oil scarcity and high oil prices [12].

The unrestricted VAR analysis allows for an assessment of the response of REI to oil prices, GDP per capita and adjusted interest rates. It provides a multivariate approach in which changes in a specific variable rely on its own lags and those of other variables. All variables in the VAR were considered jointly endogenous. The VAR model is presented as follows:

$$Z_t = \propto + \sum_{j=1}^{2} \beta j Z_{t-j} + \mu_t \quad (11)$$

where Z_t = [ΔREIt ΔOILt ΔGDPt ΔINTRt] is a vector of endogenous variables at time t; a = $(a_1, \ldots, a_4)$ is the (4 × 1) vector of constants; βj is the jth (4 × 4) matrix of AR coefficients for j = 1, 2; and $\mu_t = (\mu_{1t}, \ldots, \mu_{4t})$ is the (4 × 1) vector of error terms.

3.3. Data Gathering

This paper uses annual panel data from 1990–2018 for six African countries (Algeria, Angola, Egypt, Ethiopia, Nigeria, and South Africa). All economic data comes from the World Bank development indicator, the International Energy Agency and the International Monetary Fund's International

Financial Statistics (IFS). The major oil exporters in the sample are Nigeria, Angola and Algeria, the three petroleum exporting countries which accounted for 62% of total crude oil production from Africa in 2017 [17]. During the sample period, South Africa, Egypt and Ethiopia were primarily net oil importers in the region. In addition, the chosen variables include GDP, interest rate and oil prices. As is definitive in energy consumption models, revenue is assessed using per capita real GDP and annual GDP growth. Oil, or products originated from oil, are deemed to be the most likely alternative for renewable energy, thus oil prices are correlated to the price of a substitute [82]. The oil price series is the crude oil price (units: U.S. dollars per barrel). The interest rate is defined as the cost of borrowing, which is a key determinant of investment in the private sector. Oil price volatility is the crude oil average spot price of Brent, Dubai and West Texas intermediate, equally weighed (units: U.S. dollars per barrel). The annual oil price volatility is measured as the standard deviation of the four (average) quarterly oil prices within each year. The paper used renewable energy generation/real GDP as a proxy for REI.

The variables are appointed by economic theory and data availability. Based on a definitive accelerator procedure to investment, output growth is a substantial determinant, and according to Keynesian investment theory, investment determinations count on the alliance between the marginal efficiency of capital and interest rates, producing an inverse relationship between investment and interest rates [12]. Furthermore, for the energy sector it is vital to integrate the price of the main alternative in the form of oil prices, giving a model comprising of real oil prices, production growth and the interest rate as components that can influence REI.

4. Results

4.1. The Granger Causality Test Result

The Granger causality test is a statistical hypothesis test for determining whether one time series is useful in forecasting another. Based on the Granger causality test result (Table 2), we cannot reject the hypothesis that REI does not Granger cause Oil Price (OIL) but does allow for the rejection of the hypothesis that oil price (OIL) does not Granger cause REI.

Therefore, since REI does not Granger cause oil price, but rather oil price Granger causes REI, it is an indication that Granger causality runs one-way from oil price to REI and not the other way.

Moreover, the result also shows that we cannot reject the hypothesis that REI does not Granger cause Gross Domestic Product (GDP), but does allow for the rejection of the hypothesis that GDP does not Granger cause REI. Therefore, since Renewable Energy Investment (REI) does not Granger cause GDP, but GDP Granger causes REI, it is an indication that Granger causality runs one-way from GDP to REI and not the other way.

4.2. Variance Decomposition Analysis

Variance decomposition analysis provides the tool to determine the relative importance of the study. The result of the variance decomposition over a 24-quarter time horizon is summarized in Appendix A.

Variance decomposition shows how much of the difference in the exchange rate and domestic investment is due to the variations of the included variables in the model, including the oil shocks, and how much of the variation in the exchange rate and domestic investment is due to the variations of the included variables in the model, including the oil shocks. This study's analyses applied the advanced generalized forecast error variance decomposition to investigate the relationships among renewable energy investment, oil price, GDP, interest rate and oil price volatility, as well as to gauge the influences of the variables on each other for the short and long run.

The variance decomposition in the short run shows that 100% of forecasts in REI can be explained by the variance itself in the selected African countries. This means other variables in the model have no strong influence on REI. That is, those variables have a strong exogenous impact, in the sense that they do not influence REI at all. The variance decomposition, in the long run, shows that REI is strongly influenced by itself and oil price volatility. This shows that the influence of other variables such as oil price, GDP and interest rate in the model are not significant in African countries.

Table 2. Granger Causality Test.

VAR Granger Causality/Block Exogeneity Wald Tests			
Dependent variable: REI			
Excluded	Chi-sq	df	Prob.
OIL	0.803036	2	0.6693
GDP	0.777132	2	0.6780
INTR	0.688981	2	0.7086
OIL_PRICE_VOLATILITY	1.272458	2	0.5293
All	3.983181	8	0.8586
Dependent variable: OIL			
Excluded	Chi-sq	df	Prob.
REI	1.802414	2	0.4061
GDP	2.271591	2	0.3212
INTR	2.435771	2	0.2959
OIL_PRICE_VOLATILITY	3.099759	2	0.2123
All	8.288025	8	0.4059
Dependent variable: GDP			
Excluded	Chi-sq	df	Prob.
REI	4.681053	2	0.0963
OIL	2.900232	2	0.2345
INTR	0.694308	2	0.7067
OIL_PRICE_VOLATILITY	7.795743	2	0.0203
All	14.85180	8	0.0621
Dependent variable: INTR			
Excluded	Chi-sq	df	Prob.
REI	1.874307	2	0.3917
OIL	4.153888	2	0.1253
GDP	9.371134	2	0.0092
OIL_PRICE_VOLATILITY	0.080319	2	0.9606
All	24.48963	8	0.0019
Dependent variable: OIL_PRICE_VOLATILITY			
Excluded	Chi-sq	Df	Prob.
REI	1.156619	2	0.5608
OIL	7.941099	2	0.0189
GDP	1.272229	2	0.5293
INTR	2.646395	2	0.2663
All	13.09068	8	0.1088

Furthermore, the variance decomposition in the short run shows that 99% of forecasts in oil price can be explained by the variance itself in the selected African countries. This means other variables in the model have no strong influence on the oil price. That is, those variables have a strong exogenous impact, in the sense that they do not influence the oil price at all. The variance decomposition, in the long run, shows that oil price is strongly influenced by itself only. This shows that the influence of other variables in the model is not significant in African countries.

The variance decomposition for the GDP in the short run shows 97% of the forecast in GDP can be explained by the variance itself in the selected African countries. While the long run shows that the

GDP is strongly affected by itself only. The interest rate shows a similar result of 94% forecast in the short run, with 87% in the long run.

Finally, the variance decomposition in the short run shows that only 25% and 11% of forecasts in the short run and long run, respectively, in oil price volatility can be explained by the variance itself in the selected African countries. This means that none of the variables has an influence on the volatility in oil price in the selected African countries.

4.3. Impulse Response Function Analysis

Impulse response functions (IRFs) are dynamic simulations showing the response of an endogenous variable over time to a given shock. In this regard, Figure 1 below presents the impulse response function result of the dynamic response of REI, oil price, GDPg, interest rate and oil price volatility for a 28-year horizon and dynamic simulations showing the response of an endogenous variable over time to a given shock. In this regard, Figure 1 below presents the impulse response function result of the dynamic response of REI, oil price, GDPg, interest rate and oil price volatility for a 28-year horizon.

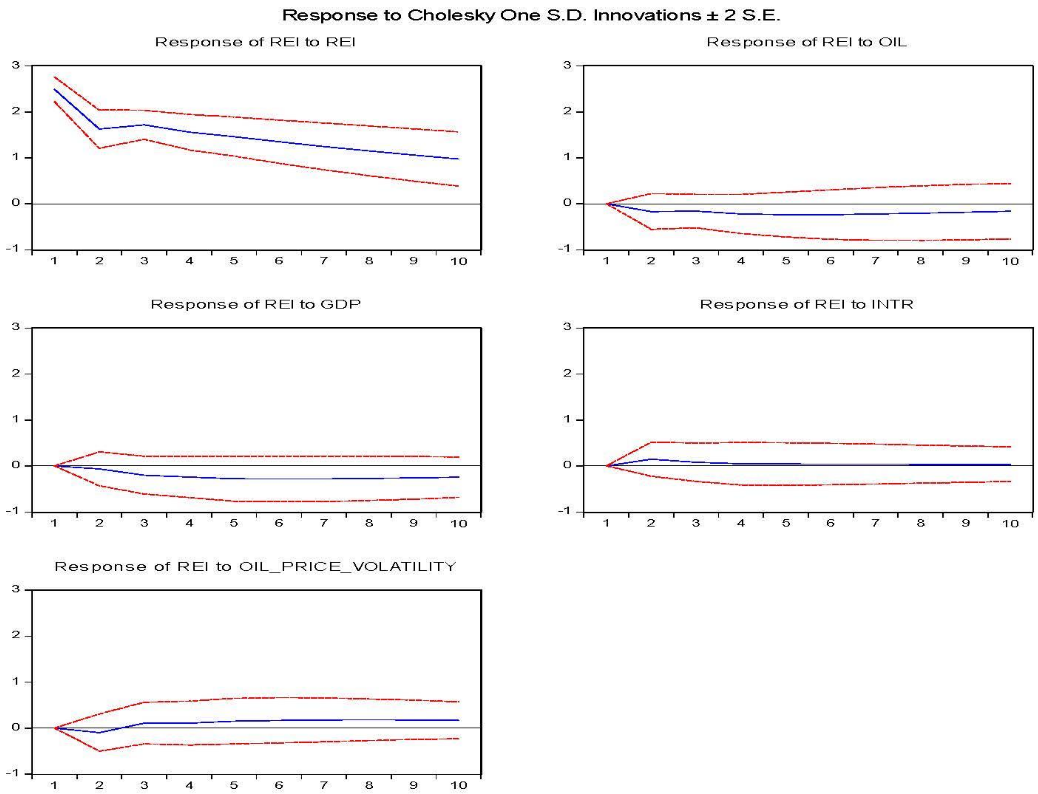

Figure 1. Results of the dynamic response of Renewable Energy Investment (REI), oil price, Gross Domestic Product growth (GDPg), interest rate and oil price volatility over 28 years.

The analyses examined the connection between REI, economic growth, interest rate and oil price volatility using IRF methodology. IRFs are only valid if the VAR is permanent, therefore, some actions must be taken to guarantee that the VAR is stable while IRFs are used to interpret the results [23]. The IRF demonstrates how a residual shock to one of the innovations in the model affects the coexisting and future values of all endogenous variables. The implication was assumed by 95% confidence durations. The omission bands were accomplished by using a Monte Carlo simulation procedure with 1000 counterparts. Analytically intended standard mistakes were employed to establish confidence intervals that were entrusted to gauge the significance of each impulse response. The IRF indicates how long, and to what extent, renewable energy consumption reacts to an accidental change in income or electricity price [87].

The result indicates that REI exhibited an immediate positive response to oil shock. However, REI continued to fluctuate negatively to the GDP. The result also shows that the REI is positive to the interest rate in Africa and finally, it exhibits an immediate negative response to oil price volatility but becomes positive after the second period.

Meanwhile, the negative response that was exhibited between the REI and the GDP disagreed with the outcome of Sodorsky [82] and Omri et al. [86] which exhibited a positive response. However, the Granger causality test revealed an insignificant causality between REI and GDP, with a significant causality between GDP and REI. This means that it is the GDP that is Granger causing the REI. This simply means that the GDP is a variable that drives REI.

5. Conclusions and Policy Implication

This study aimed to gain a clear view of the sensitivity in changes in oil prices, output growth, interest rate and oil price volatility on investment in renewable energy and examine if there is significant influence from shocks. The variance decomposition, in the long run, shows that REI is strongly influenced by itself and oil price volatility. This shows that the influence of other variables such as oil price, GDP and interest rate in the model are not significant in the selected African countries.

The results indicate that REI exhibited immediate positive responses to oil shocks. However, REI continued to fluctuate negatively in response to GDP. The result also shows that the REI responds positively to interest rate in Africa and finally, it exhibited immediate negative responses to oil price volatility but became positive after the second period.

Achieving the NDC REI targets in Africa requires a large investment from the private sector. Griffith-Jones et al. observed that considering the scale of the investment required, it is clear that a large proportion of investment in renewables will need to come from the private sector [11]. However, many countries in Africa have been neglected by energy investors as a result of the combined political risks, commercial risks and inadequate energy infrastructure from increasing investments [37]. There is a need to target and implement policies that promote commercial-scale renewable energy and attract private investment.

This research, therefore, recommends that governments of African nations should increase financial supports for the renewable energy sector and provide additional incentives, such as removing subsidies in oil prices. Furthermore, they should utilize the increased revenue and reduce public spending to subsidize renewable energy and initiate policies that could target greater commercialization of renewable energy sources. This would encourage private sector investment renewable energy despite the oil price fluctuations.

Author Contributions: Conceptualization, methodology, computing, writing–original draft preparation and reviewing and editing, I.T. Supervsion, writing–reviewing and editing, P.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

FIT	feed-in tariffs
GCC	Gulf Cooperation Council
GDP	gross domestic product
GHG	greenhouse emissions
NDCs	Nationally Determined Contributions
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of Petroleum Exporting Countries
REI	renewable energy investment
RETs	renewable energy technologies
RPS	renewable portfolio standards
TWh	terawatt-hours
VAR	vector autoregression

Appendix A

Table A1. Result of variance decomposition analysis.

Period	S.E.	REI	OIL	GDP	INTR	OIL_PRICE_VOLATILITY
		Variance Decomposition of REI:				
Period	S.E.	REI	OIL	GDP	INTR	OIL_PRICE_VOLATILITY
1	2.491680	100.0000	0.000000	0.000000	0.000000	0.000000
		(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
2	2.985265	99.28687	0.317473	0.047003	0.239605	0.109045
		(1.86286)	(1.23698)	(0.47748)	(0.57489)	(0.79153)
3	3.455906	98.76426	0.452119	0.369471	0.234492	0.179659
		(2.16223)	(1.29315)	(1.03161)	(0.68343)	(0.76560)
4	3.806240	98.14612	0.714007	0.703204	0.210173	0.226500
		(2.72229)	(1.65279)	(1.52325)	(0.87525)	(0.89491)
5	4.095762	97.46663	0.949515	1.060936	0.192342	0.330576
		(3.39799)	(2.05211)	(2.02204)	(1.06357)	(1.13395)
6	4.331109	96.86671	1.144845	1.364523	0.180375	0.443551
		(4.03149)	(2.44890)	(2.41496)	(1.24302)	(1.36874)
7	4.525093	96.33973	1.291594	1.632703	0.172702	0.563267
		(4.63262)	(2.80400)	(2.74746)	(1.41440)	(1.59319)
8	4.684906	95.90549	1.396726	1.856422	0.167880	0.673480
		(5.16149)	(3.11304)	(3.01838)	(1.57826)	(1.78726)
9	4.816946	95.55067	1.468367	2.043753	0.165209	0.772005
		(5.63017)	(3.37902)	(3.24100)	(1.73360)	(1.95303)
10	4.926125	95.26685	1.514841	2.197826	0.164055	0.856433
		(6.03412)	(3.60572)	(3.42250)	(1.87850)	(2.09086)
		Variance Decomposition of OIL:				
Period	S.E.	REI	OIL	GDP	INTR	OIL_PRICE_VOLATILITY
1	15.28973	0.093067	99.90693	0.000000	0.000000	0.000000
		(0.88102)	(0.88102)	(0.00000)	(0.00000)	(0.00000)
2	19.54667	0.338880	98.74600	0.574678	0.036380	0.304060
		(1.33959)	(2.04817)	(1.14781)	(0.44481)	(1.03306)
3	22.02240	0.360005	97.61901	1.105730	0.585911	0.329343
		(1.44050)	(2.85886)	(1.69666)	(1.30483)	(1.04311)
4	23.79715	0.462311	96.01107	1.707682	1.262090	0.556851
		(1.61592)	(4.17391)	(2.42108)	(2.33613)	(1.60010)
5	24.98372	0.521755	94.92792	2.046530	1.703971	0.799819
		(1.79795)	(5.11106)	(2.88656)	(3.06822)	(2.14572)
6	25.75271	0.560401	94.13455	2.274233	1.952095	1.078724
		(1.96548)	(5.81997)	(3.23706)	(3.54058)	(2.62722)
7	26.23726	0.582450	93.58927	2.416085	2.095551	1.316641
		(2.13370)	(6.36523)	(3.48664)	(3.85715)	(3.00089)
8	26.53764	0.593805	93.21408	2.511451	2.177685	1.502981
		(2.31180)	(6.79356)	(3.67044)	(4.07007)	(3.28010)
9	26.71961	0.598684	92.96733	2.573034	2.224801	1.636152
		(2.50287)	(7.12940)	(3.79961)	(4.21388)	(3.47161)
10	26.82784	0.599991	92.80825	2.612923	2.251343	1.727488
		(2.70569)	(7.39921)	(3.88842)	(4.31046)	(3.59744)
		Variance Decomposition of REI: Variance Decomposition of GDP:				
Period	S.E.	REI	OIL	GDP	INTR	OIL_PRICE_VOLATILITY
1	4.070147	0.013681	3.518800	96.46752	0.000000	0.000000
		(0.77319)	(2.97917)	(3.08227)	(0.00000)	(0.00000)
2	4.225296	0.302259	4.981631	93.01247	0.013525	1.690117
		(1.38820)	(3.70481)	(4.21790)	(0.65104)	(2.52146)
3	4.463315	0.627862	4.997585	91.08777	0.219222	3.067565
		(1.35409)	(3.65553)	(4.38075)	(0.86594)	(2.76721)
4	4.503840	1.040999	5.000528	90.49070	0.253723	3.214053
		(1.65358)	(3.68665)	(4.53885)	(1.03374)	(2.85042)
5	4.549767	1.560163	4.900109	89.62719	0.304148	3.608391
		(1.97869)	(3.62377)	(4.70733)	(1.18922)	(3.08303)
6	4.570948	2.099611	4.892435	88.98799	0.324798	3.695161
		(2.34415)	(3.58100)	(4.80449)	(1.27662)	(3.12457)
7	4.590525	2.653400	4.946251	88.31909	0.343843	3.737417
		(2.72078)	(3.55091)	(4.95198)	(1.34419)	(3.16687)

Table A1. *Cont.*

8	4.607052	3.177153	5.045856	87.69650	0.355413	3.725082
		(3.08357)	(3.54288)	(5.11177)	(1.38876)	(3.15758)
9	4.622460	3.661098	5.159362	87.11308	0.363931	3.702525
		(3.42054)	(3.54432)	(5.29689)	(1.42016)	(3.13977)
10	4.636476	4.092403	5.267427	86.59054	0.369020	3.680613
		(3.72466)	(3.55207)	(5.48416)	(1.44231)	(3.11357)
			Variance Decomposition of INTR:			
Period	S.E.	REI	OIL	GDP	INTR	OIL_PRICE_VOLATILITY
1	12.83066	0.049022	5.586691	0.185838	94.17845	0.000000
		(0.90185)	(3.43839)	(1.04933)	(3.72956)	(0.00000)
2	14.95729	0.037133	6.547661	0.180695	93.23444	7.02×10^{-5}
		(1.06629)	(2.42413)	(1.11671)	(3.06548)	(0.45603)
3	15.51151	0.094985	7.768503	2.082924	89.88109	0.172498
		(1.04579)	(3.18935)	(2.13748)	(3.92580)	(0.89685)
4	15.66859	0.192469	8.145631	2.911161	88.51143	0.239306
		(1.12104)	(3.60918)	(2.91073)	(4.70948)	(1.18592)
5	15.75602	0.251299	8.326291	3.460647	87.72118	0.240580
		(1.20336)	(3.86726)	(3.50242)	(5.11359)	(1.44350)
6	15.79889	0.293118	8.481800	3.641065	87.34467	0.239351
		(1.30822)	(4.08533)	(3.75746)	(5.36204)	(1.61455)
7	15.82661	0.319711	8.611548	3.727914	87.09958	0.241247
		(1.41369)	(4.26494)	(3.94250)	(5.56204)	(1.69688)
8	15.84411	0.337795	8.719984	3.757100	86.94289	0.242235
		(1.52584)	(4.41079)	(4.04053)	(5.72843)	(1.74780)
9	15.85619	0.349919	8.806437	3.767650	86.83321	0.242786
		(1.64259)	(4.52332)	(4.11186)	(5.87196)	(1.77522)
10	15.86456	0.358503	8.873159	3.769532	86.75610	0.242703
		(1.76453)	(4.60532)	(4.15107)	(5.99127)	(1.79130)
			Variance Decomposition of OIL_PRICE_VOLATILITY:			
Period	S.E.	REI	OIL	GDP	INTR	OIL_PRICE_VOLATILITY
1	18.66401	0.170972	74.75745	0.215044	0.031823	24.82471
		(1.17844)	(3.56149)	(0.42180)	(0.19782)	(3.17795)
2	23.26884	0.166593	80.16496	0.355860	0.057286	19.25530
		(1.35348)	(4.11004)	(0.81753)	(0.52350)	(3.81810)
3	26.16733	0.229357	83.02632	0.614337	0.718536	15.41145
		(1.32477)	(4.24605)	(1.21857)	(1.37156)	(3.56674)
4	28.35834	0.362196	83.98412	1.063908	1.451554	13.13823
		(1.45613)	(4.67037)	(1.82449)	(2.41792)	(3.23160)
5	29.89428	0.467205	84.31734	1.341104	1.940597	11.93375
		(1.67338)	(5.10504)	(2.26904)	(3.16063)	(3.08859)
6	30.93377	0.546078	84.31619	1.555324	2.223757	11.35865
		(1.88633)	(5.50218)	(2.62998)	(3.65260)	(3.08987)
7	31.61593	0.601754	84.20741	1.700989	2.391750	11.09810
		(2.09862)	(5.85889)	(2.89927)	(3.99179)	(3.16746)
8	32.05509	0.639112	84.06935	1.807114	2.489317	10.99511
		(2.30515)	(6.15874)	(3.10624)	(4.22369)	(3.26843)
9	32.33110	0.663284	83.94763	1.880403	2.545864	10.96282
		(2.50939)	(6.40452)	(3.25847)	(4.38260)	(3.35964)
10	32.50131	0.678250	83.85159	1.931001	2.577898	10.96126
		(2.71143)	(6.60682)	(3.36907)	(4.49040)	(3.43224)
Cholesky Ordering: REI OIL GDP INTR OIL_PRICE_VOLATILITY Standard Errors: Monte Carlo (100 repetitions)						

References

1. Oyewo, A.S.; Aghahosseini, A.; Ram, A.M.; Breyer, C. Transition towards decarbonised power systems and its socio-economic impacts in West Africa. *Renew. Energy* **2020**, *154*, 1092–1112. [CrossRef]
2. Sterl, S.; Vanderkelen, I.; Chawanda, C.J.; Russo, D.; Brecha, R.J.; van Griensven, A.; van Lipzig, N.P.; Thiery, W. Smart renewable electricity portfolios in West Africa. *Nat. Sustain.* **2020**, 1–10. [CrossRef]

3. United Nations Industrial Development Organization (UNIDO). Scaling up Renewable. Google Scholar. Available online: https://www.uncclearn.org/wp-content/uploads/library/unido11.pdf (accessed on 15 April 2020).
4. Olanrewaju, B.T.; Olususoye, E.; Adenikinju, A.; Akintande, J.O. A panel data analysis of renewable energy consumption in Africa. *Renew. Energy* **2019**, *140*, 668–679. [CrossRef]
5. Delina, L.L.; Sovacool, K.B. Of temporality and plurality: An epistemic and governance agenda for accelerating just transitions for energy access and sustainable development. *Curr. Opin. Environ. Sustain.* **2018**, *34*, 1–6. [CrossRef]
6. Adams, S.; Acheampong, A.O. Reducing carbon emissions: The role of renewable energy and democracy. *J. Clean. Prod.* **2019**, *240*, 118245. [CrossRef]
7. Bouraiou, A.; Necaibia, A.; Boutasseta, N.; Mekhilef, S.; Touaba, O. Status of renewable energy potential and utilization in Algeria. *J. Clean. Prod.* **2019**, *246*. [CrossRef]
8. Gorgulu, S. Investigation of renewable energy potential and usage in TR 61 region. *J. Clean. Prod.* **2019**, *236*, 117698. [CrossRef]
9. Yao, S.; Zhang, S.; Zhang, X. Renewable energy, carbon emission and economic growth: A revised environmental Kuznets Curve perspective. *J. Clean. Prod.* **2019**, *235*, 1338–1352. [CrossRef]
10. Apergis, N.; Payne, J.E. Renewable energy, output, CO2 emissions, and fossil fuel prices in Central America: Evidence from a nonlinear panel smooth transition vector error correction model. *Energy Econ.* **2014**, *42*, 226–232. [CrossRef]
11. Griffith-Jones, S.; Spratt, S.; Rade, R.; Griffith-Jones, E. *Investment in Renewable Energy, Fossil Fuel Prices and Policy Implications for Latin America and the Caribbean*; Financing for Development UN-ECLAC Series No. 264; Economic Commission for Latin America and the Caribbean: Santiago, Chile, 2017.
12. Shah, I.; Hiles, C.; Morley, B. How do oil prices, macroeconomic factors and policies affect the market for renewable energy? *Appl. Energy* **2018**, *215*, 87–97. [CrossRef]
13. Kebede, E.; Kagochi, J.; Jolly, C.M. Energy consumption and economic development in Sub-Saharan Africa. *Energy Econ.* **2010**, *32*, 532–537. [CrossRef]
14. Tiwari, A.K. A structural VAR analysis of renewable energy consumption, real GDP and CO_2 emissions: Evidence from India. *Econ. Bull.* **2011**, *31*, 1793–1806.
15. Karlsson, S. *Handbook of Economic Forecasting*; Elsevier: London, UK, 2013.
16. International Trade Centre. ITC by Country Report, 05/12/2015. Available online: https://www.intracen.org/country/ethiopia/#:~{}:text=Country%20Brief,growing%20economies%20in%20the%20world (accessed on 15 April 2020).
17. International Energy Agency. World Energy Balances. 2019. Available online: https://www.iea.org/subscribe-to-data-services/world-energy-balances-and-statistics (accessed on 15 April 2020).
18. Fitiwi, D.Z.; de Cuadra, F.; Olmos, L.; Rivier, M. A new approach of clustering operational states for power network expansion planning problems dealing with RES (renewable energy source) generation operational variability and uncertainty. *Energy* **2015**, *90*, 130–1376. [CrossRef]
19. Ergun, S.J.; Owusu, P.A.; Rivas, M.F. Determinants of renewable energy consumption in Africa. *Environ. Sci. Pollut. Res.* **2019**, *26*, 15390–15405. [CrossRef] [PubMed]
20. Liu, X.; Zeng, M. Renewable energy investment risk evaluation model based on system dynamics. *Renew. Sustain. Energy Rev.* **2017**, *73*, 782–788. [CrossRef]
21. Dominioni, G.; Romano, A.; Sotis, C. A quantitative study of the interaction between oil price and renewable energy sources stock prices. *Energies* **2019**, *12*, 1693. [CrossRef]
22. Kumar, S.; Managi, S.; Matsuda, A. Stock prices of clean energy firms, oil and carbon markets: A vector autoregressive analysis. *Energy Econ.* **2012**, *34*, 215–226. [CrossRef]
23. Sadorsky, P. *Modelling Renewable Energy Consumption for a Greener Global Economy. Planet Earth 2011—Global Warming Challenges and Opportunities for Policy and Practice*; Carayannis, E., Ed.; InTech: Rijeka, Croatia; Shanghai, China, 2011; pp. 507–524. Available online: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1089.2871&rep=rep1&type=pdf (accessed on 15 April 2020).
24. Inchauspe, J.; Ripple, R.D.; Truck, S. The dynamics of returns on renewable energy companies: A state-space approach. *Energy Econ.* **2015**, *48*, 235–335. [CrossRef]
25. Reboredo, J.C.; Rivera-Castro, M.A.; Ugolini, A. Wavelet-based test of co-movement and causality between oil and renewable energy stock prices. *Energy Econ.* **2017**, *61*, 241–252. [CrossRef]

26. Zhao, X. Do the stock returns of clean energy corporations respond to oil price shocks and policy uncertainty? *J. Econ. Struct.* **2020**, *53*, 1–16. [CrossRef]
27. Kyritsis, E.; Serletis, A. Oil prices and the renewable energy sector. *Electron. J.* **2017**. [CrossRef]
28. Eregha, P.B.; Mesagan, E. Energy consumption, oil price and macroeconomic performance in energy dependent African countries. *Appl. Econom.* **2017**, *46*, 74–89.
29. Troster, V.; Shahbaz, M.; Uddin, S.G. Renewable energy, oil prices, and economic activity: A Granger-causality in quantiles analysis. *Energy Econs.* **2018**, *70*, 440–452. [CrossRef]
30. Khan, M.I.; Yasmeen, T.; Shakoor, A.; Khan, N.B.; Muhammad, R. 2014 oil plunge: Causes and impacts on renewable energy. *Renew. Sustain. Energy Rev.* **2017**, *68 Pt 1*, 609–622. [CrossRef]
31. Miketa, A.; Merven, B. West African Power Pool: Planning and Prospects for Renewable Energy. U.S. Department of Energy Office of Scientific and Technical Information. 2013. Available online: https://www.osti.gov/etdeweb/biblio/22110312 (accessed on 15 April 2020).
32. Aldarraji, M.H.H.; Bakir, A. The Impact of Renewable Energy Investment on Economic Growth. *J. Soc. Sci.* **2020**, *9*. Available online: http://centreofexcellence.net/J/JSS/PDFs/jss.2020.9.2.234.248.pdf (accessed on 15 April 2020). [CrossRef]
33. Singh, N.; Nyuur, R.; Richmond, B. Renewable Energy Development as a Driver of Economic Growth: Evidence from Multivariate Panel Data Analysis. *Sustainability* **2019**, *11*, 2418. [CrossRef]
34. Marinas, M.; Dinu, M. Renewable energy consumption and economic growth. Causality relationship in Central and Eastern European countries. *PLoS ONE* **2018**, *13*, e0202951. [CrossRef]
35. Maji, I.K.; Sulaiman, C.; Abdul-Rahim, A.S. Renewable energy consumption and economic growth nexus: A fresh evidence from West Africa. *Energy Rep.* **2019**, *5*, 384–392. [CrossRef]
36. Sweerts, B.; Loga, F.D.; van der Zwaan, B. Financial de-risking to unlock Africa's renewable energy potential. *Renew. Sustain. Energy Rev.* **2019**, *102*, 75–82. [CrossRef]
37. Hafner, M.; Tagliapietra, S.; de Strasser, L. Energy investments for Africa's energy transition Challenges and Opportunites. In *Energy in Africa. Springer Briefs in Energy*; Springer: Cham, Switzerland, 2018; pp. 77–96.
38. [RES4MED] Renewable Energy Solutions for the Mediterranean and Africa. A New Instrument to Foster Large-Scale Renewable Energy Development and Private Investment in Africa. 2017. Available online: https://www.res4med.org/wp-content/uploads/2019/02/RenewAfrica-White-Paper_FINAL.pdf (accessed on 28 May 2020).
39. Klagge, B.; Nweke-Eze, C. Financing large-scale renewable energy projects in Kenya: Investor types, international connections, and financialization. *Geogr. Ann.* **2020**, *102*, 61–83. [CrossRef]
40. Walaa, M. *Private Investment in Renewable Energy Sector in Africa: An Economic Analysis*; Journal of African Studies Review; Institute of African Research and Studies: Cairo, Egypt, 2016; Volume 40, Available online: https://mpra.ub.uni-muenchen.de/79271/1/MPRA_paper_79271.pdf (accessed on 14 April 2020).
41. Schwerhoff, G.; Sy, M. Financing renewable energy in Africa—Key challenge of the sustainable development goals. *Renew. Sustain. Energy Rev.* **2017**, *75*, 393–401. [CrossRef]
42. Baker, L. The evolving role of finance in South Africa's renewable energy sector. *Geodorum* **2015**, *64*, 146–156. [CrossRef]
43. Egli, F.; Steffen, B.; Schumidt, S.T. A dynamic analysis of financing conditions for renewable energy technologies. *Nat. Energy* **2018**, *3*, 1084–1092. [CrossRef]
44. Kim, K.; Park, H.; Kim, H. Real options analysis for renewable energy investment decisions in developing countries. *Renew. Sustain. Energy Rev.* **2017**, *75*, 918–926. [CrossRef]
45. Bhattacharya, A.; Kojima, S. Power sector investment risk and renewable energy: A Japanese case study using portfolio risk optimization method. *Energy Policy* **2012**, *40*, 69–80. [CrossRef]
46. Moel, A.; Tufano, P. When are real options exercised? An empirical study of mine closings. *Rev. Financ. Stud.* **2002**, *15*, 35–64. [CrossRef]
47. Sarkar, S. On the investment-uncertainty relationship in a real options model. *J. Econ. Dyn. Control* **2000**, *24*, 219–225. [CrossRef]
48. Favero, C.A.; Hashem Pasara, M.; Sharma, S.A. A duration model of irreversible oil investment: Theory and empirical evidence. *J. Appl. Econ.* **1994**, *9*, S95–S112. [CrossRef]
49. Li, Y. Investment Decision-Making in Clean Energy under Uncertainties: A Real Options Approach. Ph.D. Thesis, Iowa State University, Ames, IA, USA, 2018. Available online: https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=7408&context=etd (accessed on 28 May 2020).

50. Bolton, R.; Foxon, T.J.; Hall, S. Energy transitions and uncertainty: Creating low carbon investment opportunities in the UK electricity sector. *Gov. Policy* **2015**, *34*, 1387–1403. [CrossRef]
51. Komendantova, N.; Patt, A.; Barras, L.; Battaglini, A. Perceptions of risks in renewable energy projects: The case of concentrated solar power in North Africa. *Energy Policy* **2012**, *40*, 103–109. [CrossRef]
52. Ackah, I.; Kizys, R. Green growth in oil producing African countries: A panel data analysis of renewable energy demand. *Renew. Sustain. Energy Rev.* **2015**, *50*, 1157–1166. [CrossRef]
53. Cao, H.; Guo, L.; Zang, L. Does oil price uncertainty affect renewable energy firms' investment? Evidence from listed firms in China. *Financ. Res. Lett.* **2020**, *33*, 101205. [CrossRef]
54. Qadan, M.; Idilbi-Bayas, Y. Risk appetite and oil prices. *Energy Econ.* **2020**, *85*, 104595. [CrossRef]
55. Fleten, S.-E.; Maribu, K.M.; Wangensteen, I. Optimal investment strategies in decentralized renewable power generation under uncertainty. *Energy* **2007**, *32*, 803–815. [CrossRef]
56. Joskow, P.L.; Tirole, J. Merchant transmission investment. *J. Ind. Econ.* **2005**, *53*, 233–264. [CrossRef]
57. Mabro, R. *Oil in the 21st Century: Issues, Challenges, and Opportunities*; Oxford University Press: Oxford, UK, 2006.
58. Fabrizio, K.R. The effect of regulatory uncertainty on investment: Evidence from renewable energy generation. *J. Lawecon. Organ.* **2013**, *29*, 765–798. [CrossRef]
59. Pueyo, A. What constraints renewable energy investment in Sub-Saharan Africa? A comparison of Kenya and Ghana. *World Dev.* **2018**, *109*, 85–100. [CrossRef]
60. Barradale, M.J. Impact of Policy Uncertainty on Renewable Energy Investment: Wind Power and PTC. USAEE Working Paper No. 08-003. 2008. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1085063 (accessed on 5 May 2020).
61. Eryilmaz, D.; Homans, F.R. How does uncertainty in renewable energy policy affect decisions to invest in wind energy? *Electr. J.* **2016**, *29*, 64–71. [CrossRef]
62. Burns, K. On the Relationship between Policy Uncertainty and Investment in Renewable Energy. *IAEE Energy Forum Montr. Spec. Issue* **2017**, 33–35. Available online: https://www.google.com.hk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwitrOvxrN7tAhXFMN4KHfodAasQFjAAegQIAhAC&url=https%3A%2F%2Fwww.iaee.org%2Fen%2Fpublications%2Fnewsletterdl.aspx%3Fid%3D833&usg=AOvVaw0yFcT02g_ukrCmoiAZPwDW (accessed on 14 April 2020).
63. Berntsen, M.; Bøe, K.S.; Jordal, T.; Molnar, P. Determinants of oil and gas investments on the Norwegian Continental Shelf. *Energy* **2018**, *148*, 904–914. [CrossRef]
64. Bøe, K.S.; Jordal, T.; Mikula, S.; Ad Molar, P. Do political risks arm development of oil fields? *J. Econ. Behav. Organ.* **2019**, *157*, 338–358. [CrossRef]
65. Horn, A.; Kjaerland, F.; Molnar, P.; Steen, B.W. The use of real option theory in Scandinavia's largest companies. *Int. Rev. Financ. Anal.* **2015**, *41*, 74–81. [CrossRef]
66. Narayan, A.; Ponnambalam, K. Risk averse stochastic programming approach for microgrid planning under uncertainty. *Renew. Energy* **2017**, *101*, 399–408. [CrossRef]
67. Venetsanos, K.; Angelopoulou, P.; Tsoutsos, T. Renewable energy sources project appraisal under uncertainty: The case of wind energy exploitation within a changing energy market development. *Energy Policy* **2002**, *30*, 297–307. [CrossRef]
68. Murto, P. Timing of Investment under Technological and Revenue Related Uncertainties. *J. Econ. Dyn. Control* **2003**, *31*, 1473–1497. [CrossRef]
69. Wustennhagen, R.; Menichetti, E. Strategic choices for renewable energy investment: Conceptual framework and opportunities for further research. *Energy Policy* **2012**, *40*, 1–10. [CrossRef]
70. Pegels, A. Renewable energy in South Africa: Potentials, barriers ad options for support. *Energy Policy* **2010**, *38*, 4945–4954. [CrossRef]
71. Sendstad, L.H.; Chronopoulos, M. Sequential investment in renewable energy technologies under policy uncertainty. *Energy Policy* **2020**, *137*, 111152. [CrossRef]
72. Gugler, K.; Haxhimusa, A.; Liebensteiner, M.; Schindler, N. Investment opportunities, uncertainty, and renewables in European electricity markets. *Energy Econ.* **2020**, *85*, 104575. [CrossRef]
73. Kinias, I.; Tsakalos, I.; Konstantopoulos, N. Investment evaluation in renewable projects under uncertainty, using real options analysis: The case of wind power industry. *Invest. Manag. Financ. Innov.* **2017**, *14*, 96–103. [CrossRef]

74. Akintande, J.O.; Olubusoye, E.O.; Adenikinju, F.A.; Olanrewaju, T.B. Modelling the determinants of renewable energy consumption: Evidence from the five most populous nations in Africa. *Energy* **2020**, *206*, 117992. [CrossRef]
75. Alabi, O.; Ackah, I.; Lartey, A. Re-visiting the renewable energy–economic growth nexus Empirical evidence from African OPEC countries. *Int. J. Energy Sect. Manag.* **2017**, *11*. [CrossRef]
76. Apergis, N.; Payne, J.E. Renewable Energy, Output, Carbon Dioxide Emissions, and Oil Prices: Evidence from South America. 2015. Available online: https://www.tandfonline.com/doi/full/10.1080/15567249.2013.853713?casa_token=F-KbsQXdKhoAAAAA%3ANPm8i6rfAPJsmtHiOwyksJhmf8OnW7fkjkNWQvNpqIAds6OtCR5CCOOhgF8EsybjePBEW8ZOkZE (accessed on 15 April 2020).
77. Polzin, F.; Migendt, M.; Taube, A.D.; van Flotow, P. Public policy influence on renewable energy investments—A panel data study across OECD countries. *Energy Policy* **2015**, *80*, 98–111. [CrossRef]
78. Wei, Y.; Guo, X. An empirical analysis of the relationship between oil prices and the Chinese macro-economy. *Energy Econs.* **2016**, *56*, 88–100. [CrossRef]
79. Al-Maamary HM, S.; Kazem, A.H.; Chaichan, T.M. The impact of oil price fluctuations on common renewable energies in GCC countries. *Renew. Sustain. Energy Rev.* **2017**, *75*, 989–1007. [CrossRef]
80. Blazquez, J.; Hunt, L.C.; Manzano, B. Oil subsidies and renewable energy in Saudi Arabia: A general equilibrium approach. *Energy J.* **2017**, *38*. [CrossRef]
81. Abid, M. The long-run and short-run effects of oil price on energy consumption in Tunisia: Evidence from structural breaks analysis. Energy Sources, Part B: Economics. *Plan. Policy* **2020**, *15*, 252–277.
82. Sadorsky, P. Renewable energy consumption, CO_2 emissions and oil prices in the G7 countries. *Energy Econ.* **2009**, *31*, 456–462. [CrossRef]
83. Gouriéroux, C.; Monfort, A.; Renne, J. Statistical inference for independent component analysis: Application to structural VAR models. *J. Econom.* **2017**, *196*, 111–126. [CrossRef]
84. Sims, C.A. Macroeconomics and Reality. *Econometrica* **1980**, *48*, 1–48. [CrossRef]
85. Chiu, C.; Mumtaz, H.; Pinter, G. Forecasting with VAR models: Fat tails and stochastic volatility. *Int. J. Forecast.* **2017**, *33*, 1124–1143. [CrossRef]
86. Omri, A.; Nguyen, K.D. On the determinants of renewable energy consumption: International evidence. *Energy* **2014**, *72*, 554–560. [CrossRef]
87. Lee, C.; Chiu, Y. Nuclear energy consumption, oil prices, and economic growth: Evidence from highly industrialized countries. *Energy Econ.* **2011**, *33*, 236–248. [CrossRef]