Avazkhodjaev, Salokhiddin; Dhiensiri, Nont; Rakhimov, Eshmurod

Article

Effects of crude oil price uncertainty on fossil fuel production, clean energy consumption, and output growth : an empirical study of the US

International Journal of Energy Economics and Policy

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(6), 371-383.

Effects of Crude Oil Price Uncertainty on Fossil Fuel Production, Clean Energy Consumption, and Output Growth: An Empirical Study of the U.S.

Salokhiddin Avazkhodjaev[1]*, Nont Dhiensiri[1], Eshmurod Rakhimov[2]

[1]College of Business and Technology, Northeastern Illinois University, USA, [2]Department of Macroeconomic Policy and Forecasting, Tashkent State University of Economics, Uzbekistan. *Email: S-avazkhodjaev@neiu.edu

Received: 14 July 2024 **Accepted:** 06 October 2024 **DOI:** https://doi.org/10.32479/ijeep.17188

ABSTRACT

This study investigates the impact of crude oil price uncertainty on U.S. fossil energy production, clean energy consumption, and economic output growth from January 2000 to June 2024. Employing the Nonlinear Autoregressive Distributed Lag (NARDL) model, the analysis captures both short-term and long-term asymmetric effects among the variables. The findings reveal that crude oil price uncertainty exerts a significant negative influence on fossil fuel production in both the short and long terms. Conversely, while renewable energy consumption initially responds positively to crude oil price volatility in the short run, this effect becomes significantly negative over the long term. Additionally, crude oil price uncertainty consistently has a significant negative impact on output growth in both the short and long runs. The Generalized Impulse Response Function (GIRF) analysis within a Vector Autoregression (VAR) framework demonstrates that shocks to crude oil prices result in sustained declines in both fossil energy production and renewable energy consumption, with reductions of approximately −0.003% points within 5-6 months. The adverse effect on output growth intensifies over time, underscoring the prolonged economic repercussions of oil price uncertainty. The study highlights that linear models are insufficient for capturing the complexities of oil price volatility, as corroborated by Wald test results. In response to these findings, the study offers several policy recommendations to enhance economic stability. These include prioritizing energy source diversification to reduce reliance on volatile fossil fuels, establishing stabilization mechanisms such as strategic reserves and price stabilization funds, and fostering the transition to clean energy through increased investment and technological advancement. Furthermore, implementing counter-cyclical fiscal measures and investing in infrastructure can help stabilize the economy during downturns, while enhanced monitoring and forecasting capabilities are crucial for effectively managing oil price trends.

Keywords: Crude Oil Price, Fossil Energy, Clean Energy, Output Growth, Asymmetric Analysis, Nonlinear Autoregressive Distributed Lag-Error Correction Model

JEL Classifications: F47, G15, G17, Q20, Q40

1. INTRODUCTION

Crude oil price volatility has long been a focal point of economic research due to its substantial influence on various sectors, notably fossil fuel production, renewable energy adoption and economic growth. The erratic nature of crude oil prices significantly impacts investment decisions, production levels, and policy formulations within the energy market. Understanding these dynamics is particularly critical for the United States, one of the largest global producers and consumers of energy, where both fossil fuels and clean energy sources are integral to the economy. Crude oil price shocks directly influences fossil fuel production because the profitability and sustainability of extraction activities are closely tied to price levels. When prices surge, producers are motivated to increase output to maximize profits. Conversely, price drops can lead to reduced production due to lower profit margins and potential financial losses (Baffes, 2021). This variability not only affects the immediate supply of fossil fuels but also impacts long-term investments in extraction technologies and infrastructure (Smith, 2020).

The relationship between crude oil price shocks, clean energy consumption and output grwoth is complex. Elevated crude oil prices often make clean energy sources more competitive, prompting a shift towards renewable energy (Hamilton, 2018). Conversely, when oil prices are low, the cost advantage of clean energy diminishes, potentially decelerating the transition to a greener energy mix (Jones et al., 2019). This dynamic interplay influences energy policy and investment decisions, shaping the overall energy landscape in the United States. Thus, scientists and policymakers in the US and globally are examining the factors of fossil fuel energy price uncertainty that can enhance the consumption of clean energy sources and its effects on industrial production. These factors include government programs (such as rebates, subsidies, or tax credits) and the creation of renewable certificates (Apergis and Payne, 2010; Kaygusuz, 2007).

Crude oil price volatility also has broader economic implications, impacting output growth and economic stability. Sharp fluctuations in oil prices can generate economic uncertainty, affecting consumer spending, business investment, and overall economic performance (Kilian, 2022). The United States, with its diverse energy portfolio, experiences these impacts across various sectors, from transportation to manufacturing, highlighting the need for effective management of price volatility to sustain economic growth (Baumeister and Peersman, 2020). Recent trends indicate increasing volatility in crude oil prices due to geopolitical tensions, supply chain disruptions, and shifts in global demand patterns (EIA, 2023). These trends underscore the importance of developing robust strategies to mitigate the adverse effects of price volatility on fossil fuel production and clean energy consumption. Policymakers are increasingly focused on promoting energy diversification and resilience to ensure stable economic growth and a sustainable energy future (Caldara et al., 2021). Empirical insights from the United States provide a comprehensive understanding of the impacts of crude oil price shocks on fossil fuel production, clean energy consumption, and output growth. By examining these relationships, this study aims to contribute to the ongoing discourse on energy economics and policy, offering valuable perspectives for stakeholders in the energy sector and beyond.

Historically, the volatility of crude oil prices has been attributed to various factors, including geopolitical events, market speculation, and changes in global supply and demand dynamics. For instance, political instability in key oil-producing regions can cause sudden supply disruptions, leading to price spikes (Hamilton, 2018). Similarly, economic sanctions or trade embargoes can reduce the availability of oil on the global market, exacerbating price volatility. The Russian-Ukrainian war has significantly impacted crude oil prices by creating substantial uncertainty and disrupting supply chains. Sanctions on Russian oil exports and the reduction of Russian oil in the global market have led to price increases and heightened volatility. Market speculation also plays a critical role, as traders' perceptions of future supply and demand conditions can lead to significant price swings. The advent of financial instruments such as futures contracts has amplified these speculative activities, adding another layer of complexity to oil price movements (Kilian, 2022).

In the context of fossil fuel production, price volatility can profoundly affect investment and operational decisions. High oil prices typically encourage investments in exploration and production activities, as the potential returns justify the substantial costs and risks involved. However, the capital-intensive nature of these activities makes producers vulnerable to price downturns, which can lead to project delays, cancellations, or even bankruptcies in extreme cases (Baffes, 2021). This cyclical investment pattern contributes to the overall volatility of the oil market, as periods of high investment and increased production capacity are often followed by supply gluts and price crashes. Furthermore, The impact of fossil fuel price volatility on clean energy consumption is equally significant but operates through different mechanisms. When oil prices are high, the relative cost advantage of clean energy technologies such as wind, solar, geothermal, biomass and biofuels becomes more pronounced. This price differential can accelerate the adoption of clean energy solutions, as both consumers and businesses seek to reduce their energy costs and hedge against future price increases (Jones et al., 2019). Additionally, high oil prices can stimulate policy measures aimed at promoting energy efficiency and reducing dependence on fossil fuels. Governments may implement subsidies, tax incentives, or regulatory mandates to encourage the deployment of clean energy infrastructure and technologies (Hamilton, 2018).

The broader economic impacts of crude oil price volatility extend beyond the energy sector, affecting macroeconomic indicators such as inflation, employment, and gross domestic product (GDP) growth. Oil price shocks can lead to inflationary pressures, as higher energy costs are passed through to consumers in the form of increased prices for goods and services (EIA, 2023). This can erode purchasing power and dampen consumer spending, which is a key driver of economic growth. In addition, sectors heavily reliant on energy inputs, such as transportation and manufacturing, may experience reduced profitability and lower output during periods of high oil prices.

It is widely accepted that recent increases in nonrenewable energy prices have coincided with a surge in renewable energy utilization. Kilian (2008) provides evidence that gasoline consumption dramatically decreases in response to unexpected energy price increases. In the U.S., pivotal factors explaining renewable energy consumption growth include concerns about dependency on foreign fossil energy (Bowden and Payne, 2010), high volatility in energy market prices, and fears of persistently high inflation caused by expensive oil prices (Kilian et al., 2021).

In a more recent study, Avazkhodjaev et al. (2024) studied the relationships between renewable energy investments and Islamic and conventional stock markets in the US, UK, and EU from January 1, 2002, to August 1, 2023. Using the Nonlinear Autoregressive Distributed Lag (NARDL) model, they found that green energy investments positively impact long-term conventional stock markets in the US and EU, with no significant effect in the

UK. Short-term effects include positive influences on Islamic markets and the EU conventional market, but a negative impact on the US conventional market. These findings emphasize the need for portfolio diversification and hedging for environmentally conscious investors. Additionally, various empirical studies have explored the relationship between the returns of energy and commodity market prices (Sadorsky, 1999; Hammoudeh and Choi, 2007; Salisu and Oloko, 2015). Other researchers have focused on examining the impact of investor sentiment on energy and commodity markets(Mamasobirov et al., 2023; Wang et al., 2013; Aloui et al., 2018; Mamasobirov et al., 2023; Perez-Liston et al., 2016; Dash and Maitra, 2017; Hasanov and Avazkhodjaev, 2022; Shakhabiddinovich et al., 2022; Avazkhodjaev et al., 2022).

Despite the extensive literature on energy prices, a significant gap remains in both theoretical and empirical research. The implications of nonrenewable energy price shocks for clean energy forms are ambiguous at best, and the prevailing approach focuses on immediate timing and current effects. It remains unclear whether energy price surges immediately affect renewable usage or if policymakers and consumers should expect short, medium, or long-term delays. Furthermore, it is also uncertain whether energy prices can help forecast U.S. renewable consumption. This gap is critical for policymakers and researchers involved in sustainability efforts, as they may benefit from further clarity on these questions, especially in policy formulation.

This paper stands out from other empirical studies on this topic by focusing specifically on the impact of crude oil price uncertainty on fossil fuel energy production, clean energy consumption, and output growth. We make three main contributions to this research area. First, we highlight that the volatility of crude oil prices has significant implications for fossil fuel production, clean energy consumption, and economic output in the United States. Understanding these complex relationships is vital for crafting policies that achieve economic stability, energy security, and environmental sustainability. By analyzing empirical evidence within this broader economic context, our study aims to offer valuable insights for stakeholders in the energy sector and contribute to the ongoing dialogue on energy economics and policy.

Second, we propose that examining the relationship between these variables in a nonlinear context is crucial for two reasons: (1) time series data may have hidden cointegration if the positive and negative components are cointegrated (Granger and Yoon, 2002), and (2) asymmetries, a type of nonlinearity, significantly affect market dynamics, especially during marked sample periods. To investigate these aspects, we use the Nonlinear Autoregressive Distributed Lag (NARDL) approach by Shin et al. (2014), which allows us to test for long-run and short-run asymmetries and accommodates time series with different orders of integration.

Third, we also use Generalized Impulse Response Function analysis (Koop et al., 1996) to examine how gold and energy prices respond to uncertainty in Islamic stock prices. Additionally, we apply the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMQ) tests of the recursive residuals (Brown et al., 1975) to ensure the robustness of our findings. This thorough analysis can help inform future policy recommendations.

The rest of this paper is organized as follows: Section 2 provides a literature review. Section 3 details the data and descriptive statistics. Section 4 outlines the empirical methodology and model specifications. Section 5 presents and discusses the empirical results. Finally, Section 6 offers conclusions and policy implications.

2. LITERATURE REVIEW

There is a substantial body of theoretical literature examining the relationship between non-renewable energy prices, fossil energy production, renewable energy consumption, and economic growth (e.g., Nicolini and Tavoni, 2017; Yang et al., 2019; Martelli et al., 2020; and Zeng et al., 2021). Much of this literature argues that non-renewable and renewable energy sources act as substitutes. According to economic theory, an increase in fossil fuel energy prices should lead to a decrease in its demand and a corresponding increase in the consumption of renewable energy. Sadorsky (2009) supports this view, developing a model of renewable energy consumption, CO_2 emissions, and oil prices for the G7 countries. Similarly, Silk and Joutz (1997) argue that rising natural gas prices will compel electric utilities to switch to alternative fuels, driven by the need to retain customers. Zhao et al. (2021) use a dynamic recursive computable equilibrium model to show that higher international oil prices spur investment in renewable energy, suggesting that renewable energy is a viable alternative to fossil fuels. They also provide evidence that renewable energy can mitigate the adverse impact of fossil fuel price fluctuations.

Acemoglu et al. (2012; 2014) introduce models with environmental constraints, demonstrating that temporary taxes on non-renewable energy can promote sustainable growth if renewable and non-renewable energy sources are sufficiently substitutable. The degree of substitutability in their framework depends on price and market size effects. Other studies, such as Ambec and Crampes (2012) and Benchekroun et al. (2019), also support the substitutability between these energy sources.

However, if renewable and non-renewable energy sources are not perfectly substitutable, some degree of complementarity is expected. In such cases, an increase in non-renewable energy prices, which decreases the quantity demanded, could also lead to a decrease in renewable energy consumption. Daly (1990) suggests that non-renewable resources can be exploited sustainably by pairing their depletion with the creation of renewable substitutes. Bastianoni et al. (2009) incorporate Daly's ideas into a model, showing that effective environmental policy relies on the complementarity between non-renewable and renewable resources. Kumar et al. (2015) find a complementary relationship between non-renewable and renewable energy in eight industries, while the substitute relationship holds for four industries.

Furthermore, Bebonchu et al. (2023) examine the impact of non-renewable energy prices on U.S. renewable energy consumption from 1973 to 2018. Using VAR models, they position non-renewable energy prices ahead of renewable consumption measures. Their findings indicate that non-renewable energy price shocks positively affect renewable energy consumption. Including nonlinearities and asymmetries in prices enhances the response significance, although non-renewable prices explain only a small variation in renewable consumption. Nonetheless, these prices improve forecast performance compared to simple autoregressive models.

Morevover, Haozhi et al. (2022) investigate the dynamic relationship between clean energy stock markets and energy commodities in China from March 2018 to July 2022. Using a time-frequency perspective, they find that clean energy stocks are primary short-term contributors and recipients, while commodities play a key long-term role. Short-term spillovers generally dominate, except during COVID-19, when long-term effects become prominent. Clean energy stocks significantly influence short-term energy commodities, and COVID-19 enhances hedging effectiveness, highlighting dynamic interactions for policymakers. Likewise, Hashem et al. (2023) explore co-movements between energy sources, CO_2 emissions, and GDP per capita in Saudi Arabia using spectral Granger causality. Their results show that non-renewable energy sources increase carbon emissions and drive long-term economic growth, while renewable sources reduce emissions and support growth across various frequencies. Wavelet plots reveal discrepancies in variables over time, with non-renewable sources contributing to pollution and renewable sources enhancing a cleaner environment. They recommend that Saudi Arabia invest in green energy for socio-economic benefits.

Similary, Shakhabiddinovich et al. (2022) apply the nonlinear ARDL (NARDL) approach to study the asymmetric impacts of renewable energy production and clean energy prices on the green economy in Asia, Europe, and the US. Their findings reveal that renewable energy production significantly positively influences green economy stock prices. However, clean energy prices have both positive and negative significant effects on the green economy across the examined regions. Short-run coefficients indicate a strong positive effect of clean energy stock prices on green economy stock prices. Additionally, negative shocks in renewable energy generation and clean energy prices have a more substantial impact than positive shocks, highlighting complex relationships between these variables and green economy stock prices. The study, however, does not explore the persistence of these short-run and long-run effects in the selected economies.

Salari et al. (2021) investigate the causal nexus between economic growth and energy consumption in the US. The authors apply four known hypotheses: Growth, conservative, feedback, and neutral, differentiating between renewable and non-renewable energy consumption. Results for renewable energy, industrial energy, and residential energy consumption show more support for the growth hypothesis. Their findings have policy implications for optimizing decisions and investments to efficiently improve economic growth while reducing energy consumption. Li and Leung (2021) evaluate the renewable energy-economic growth nexus in seven European countries from 1985 through 2018. In their study, long-run causality is found to flow from all explanatory variables to renewable energy consumption. Short-run causality is also detected from fossil fuel prices to renewable energy consumption. The authors provide empirical support for the significant role of economic growth and non-renewable energy prices in the renewable energy transition. Their findings show no evidence of Granger causality from renewable energy consumption to economic growth.

Several studies utilize the VAR-based connectedness index method to explore dynamic spillovers between financial and energy markets (e.g., Bouri et al., 2021; Jena et al., 2021; Cao and Xie, 2022; Umar et al., 2022). Gabauer and Gupta (2018) distinguish between internal and external connectedness in dynamic spillovers, while Wang and Lee (2020) use this method to analyze spillovers between category policy uncertainty and WTI crude oil markets. Despite its usefulness, the VAR-based approach is confined to the time domain. The Baruník and Křehlík (2018) method addresses this limitation by revealing time-frequency spillovers. Naeem et al. (2020) apply this method to study time-frequency connectedness between oil and clean energy markets, and Liu et al. (2022) use it to investigate dynamic risk spillovers with international stock market data. To our knowledge, this is the first study to explore the dynamic relationship between clean energy stock markets and energy commodity markets in China using the Baruník and Křehlík (2018) method from a time-frequency perspective.

The primary purpose of this paper is to empirically assess the impact of crude oil price uncertainty on fossil fuel energy production, clean energy consumption, and output growth to determine the degree of substitutability and complementarity between these energy sources. A crude oil price shocks that increases clean energy consumption and output growth would support the theoretical arguments for substitutability between the two energy sources. Conversely, a decrease in clean energy consumption would indicate complementarity. The theoretical literature suggests that the nature of the relationship may vary depending on the time horizon (short, medium, or long-term) under consideration, making it possible to observe both effects.

3. DATA AND DESCRIPTIVE STATISTICS

We utilize comprehensive data from both non-renewable and renewable energy markets to represent crude oil prices and energy commodities. The sample period spans from January 2020 to June 2024, with monthly data intervals. Crude oil prices are proxied using the Crude Oil WTI Futures from www.investing.com. For fossil fuel energy production and clean energy consumption, we sourced data from the U.S. Energy Information Administration (EIA). Additionally, the Index of Industrial Production, sourced from the Federal Reserve Economic Database (FRED) provided by the Federal Reserve Bank of St. Louis, serves as a proxy for output growth.

Table 1. provides descriptive statistics for crude oil prices, fossil fuel production, clean energy consumption, and output growth across the sample period. The monthly series and their returns are derived from the first differences of natural logarithms. These statistics specifically cover crude oil price volatility (WTI), fossil

Table 1: Descriptive statistics for monthly series of selected variables

Series	WTI	FFP	REC	IIP
Mean	4.0639	1.6885	6.1770	4.5752
Median	4.1524	1.6468	6.2601	4.5907
Maximum	4.8947	2.0143	6.5852	4.6442
Minimum	2.9035	1.4607	5.6344	4.4379
St. Deviation	0.4469	0.1511	0.2737	0.0522
Skewness	−0.5295	−0.5939	−0.3770	−0.6173
Kurtosis	2.3706	1.9638	1.6860	2.3031
Jarque-Bera	18.653***	30.539***	28.212***	24.706***

Significance level *, **, ***indicated 10%, 5% and 1%, respectively. In this context, WTI, FFP, REC, and IIP correspond to the logarithmic changes in crude oil prices, fossil fuel production, clean energy consumption, and output growth, respectively

fuel production (FFP), clean energy consumption (CEP), and industrial output growth (IIP). The estimation of crude oil price volatility and its effects was carried out using RStudio and EViews. Figure 1. illustrates the trends in returns and monthly data for crude oil prices, fossil fuel production, clean energy consumption, and output growth. A general analysis of the graphs indicates that all the selected variables have seen a significant increase over the past two decades, with a notable decline observed in the years 2020-2021.

The data presented in Table 1. illustrate that the averages of the monthly series consistently surpass their respective standard deviations. A closer look at crude oil price values shows that the maximum and minimum figures are relatively close, signaling limited variation within this sector. In contrast, fossil fuel production, clean energy production, and output growth display much lower standard deviations compared to the crude oil price series, indicating more stability in these areas. The presence of statistically significant skewness and kurtosis further suggests that the distribution of returns deviates from normality, which has important implications for risk evaluation.

These results imply that the variables analyzed demonstrate conditional heteroskedasticity, particularly given the sample size utilized in this study. This characteristic is crucial in understanding the volatility and potential risks associated with the data, emphasizing the need for careful consideration in risk assessments and economic modeling.

Given that a robust nonlinear framework necessitates the stationarity of all series under examination, our initial step involves testing for the presence of a unit root using the standard Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests on the data series in question. These tests are instrumental in determining the existence of a unit root. The results, as detailed in Table 2, reveal that the variables are non-stationary at their levels.

However, stationarity is achieved when analyzing their first differences, which account for both intercept and trend. It is important to highlight that when variables are integrated of order one or higher, denoted as I(1), the Nonlinear ARDL approach provides results consistent with alternative cointegration methodologies, such as those outlined by Fousekis et al. (2016). This consistency allows us to confidently proceed with cointegration testing within a nonlinear context. In essence, the tests robustly reject the null hypothesis of a unit root at a 1% significance level, indicating that the returns adhere to a stationary process, irrespective of the inclusion of a trend variable within the model.

4. EMPIRICAL METHODOLOGY

We apply the nonlinear autoregressive distributed lag (NARDL) model to investigate the asymmetric effects of crude oil price uncertainty on fossil energy production, clean energy consumption and output growth, considering both long-term and short-term perspectives. The NARDL approach, developed by Shin et al. (2014), is particularly useful for examining asymmetries across different time horizons. This methodology is known for its robustness in producing empirical results, even with small sample sizes (Siddiki, 2001; Narayan and Narayan, 2007; Pesaran et al., 2001), and can be employed regardless of the series' integration order, provided it does not exceed the first order. The integration order can be confirmed through unit root tests. Additionally, the identification of cointegration in the time series through their positive and negative components (Granger and Yoon, 2002) suggests the existence of nonlinear cointegration. To further ensure the robustness of our findings, we utilized a generalized impulse response function analysis among the variables and applied the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMQ) of the recursive residuals (Brown et al., 1975).

4.1. Nonlinear Autoregressive Distributed Lag (NARDL) Model

The NARDL approach provides a method for modeling asymmetric cointegration by utilizing positive and negative partial sum decompositions, which allows for the identification of asymmetric effects in both the short and long term. Furthermore, it supports the joint analysis of non-stationarity and nonlinearity within an unrestricted error correction model. The nonlinear cointegration regression, as described by Shin et al. (2014), is formulated as follows:

$$y_t = \beta^+ x_t^+ + \beta^- x_t^- + \mu_t \tag{1}$$

were β^+ and β^- are long term parametres of k × 1 vector of regressors x_t, decomposed as:

$$x_t = x_0 + x_t^+ + x_t^- \tag{2}$$

Where $x_t^+ \, and \, x_t^-$ are the partial sums of positive or negative change in x_t as follows:

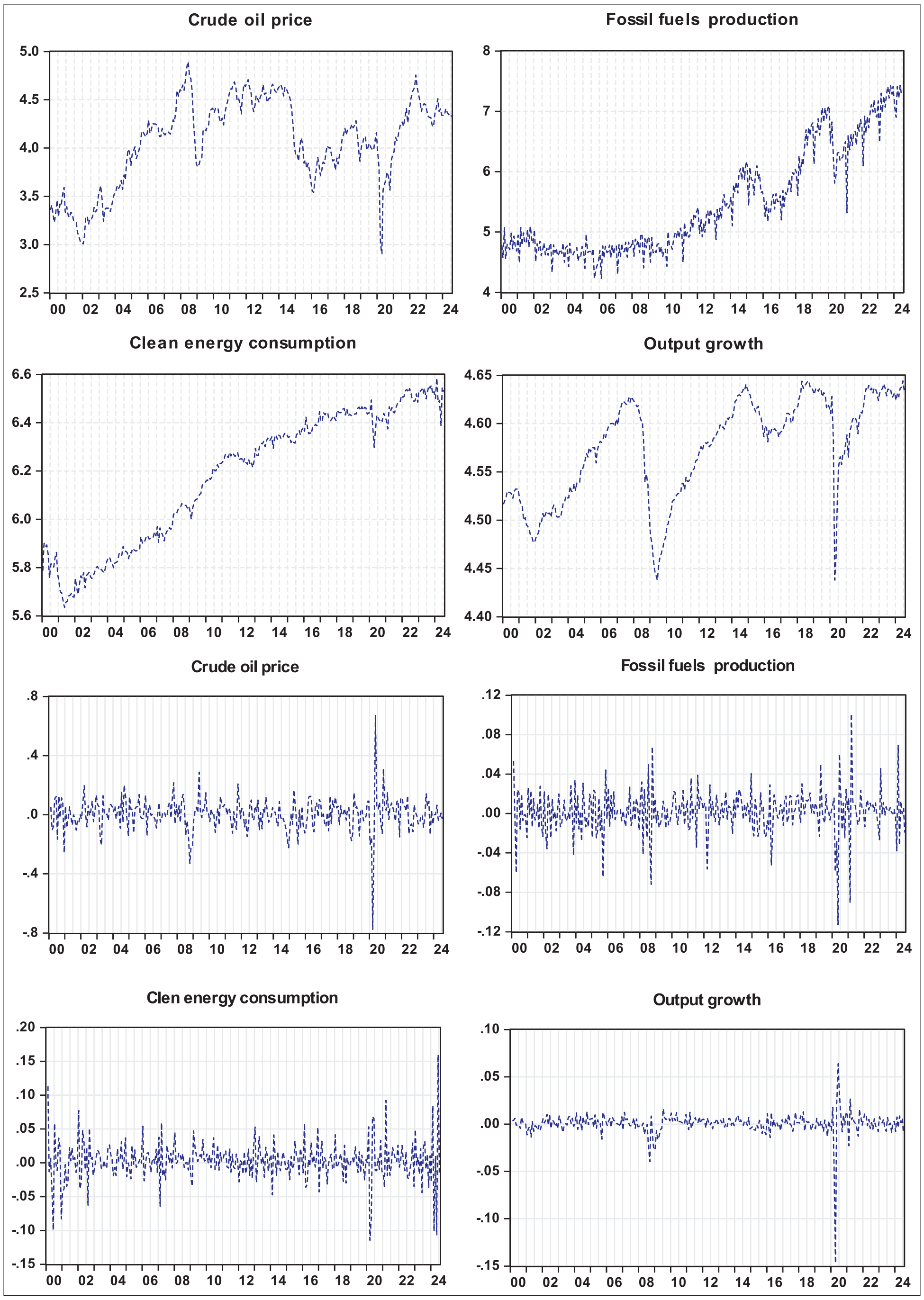
$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} \max(\Delta x_{j,} 0) \tag{3}$$

$$x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} \min(\Delta x_{j,} 0) \tag{4}$$

4.2. Nonlinear ARDL-Error Correction Model

The NARDL (p,q) from of the Eq.(2), in the form of asymmetric error correction model (ECM) (Raza et al., 2016) can be presented as follows:

Figure 1: Evolution of return and monthly series of selected variables under study



$$\Delta y_t = \rho y_{t-1} + \theta^+ x_{t-1}^+ + \theta^- x_{t-1}^- + \sum_{j=1}^{p-1} \varphi_j \Delta y_{t-j} + \sum_{j=0}^{p} (\pi_j^+ \Delta x_{t-j}^+ + \pi_j^- \Delta x_{j-t}^-) + \varepsilon_t \quad (5)$$

Where $\theta^+ = -\rho\beta^+$ and $\theta^- = -\rho\beta^-$. In nonlinear framework, the first two steps to ascertain cointegration between the varibales are same is in linear ARDL bound testing procedure i.e. estimation Eq. (5) using OLS and conduction the joint null ($\rho = \theta^+ = \theta^- = 0$) hypothesis test of no asymmetric relationship. However, in NARDL, the Wald test is used to examine the long-run ($\theta^+ = \theta^-$) and short-run ($\pi^+ = \pi^-$) aysmmetries in the relationship.

Finally, the asymmetric cumulative dynamic multiplier effects of a unit change in $x_t^+ \, and \, x_t^-$ on y_t can be calculated as follows:

$$v_h^+ = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^+}, v_h^- = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^-}, h = 0,1,2,\ldots. \quad (6)$$

Where as $h = \infty$, the $v_h^+ \to \beta^+$ and $v_h^- \to \beta^-$. A mentioned above β^+ and β^- are the asymmetric long-run coefficients and here can be examines as $\beta^+ = -\theta^+/\rho$ and $\beta^- = -\theta^-/\rho$, respectively.

4.3. Generalized Impulses Response Function Analysis (GIRF)

To analyze the temporal effects of crude oil price uncertainty on fossil energy production, clean energy consumption, and output growth, we employ the Generalized Impulse Response Function (GIRF) methodology proposed by Koop et al. (1996). We have constructed an analytical framework that examines the impulse responses of crude oil price uncertainty to a one-unit change in fossil energy production, clean eneryg consumption and output growth within a VAR process. The specifics of the GIRF used in this study are detailed as follows, based on the approach outlined by Grier et al. (2004):

$$GIRF_K\left(n,\varrho_t,\omega_{t-1}\right)=E\left[K_{t+n}\left|\varrho_t,\omega_{t-1}\right.\right]-E\left[K_{t+n}\left|\omega_{t-1}\right.\right] \quad (7)$$

Where n = 0,1,2,3., thus the GIRF is conditional on ϱ_t and ω_{t-1} and constructed the responses by average future shocks given in the previous and present. Giving it, a natural reference point for GIRF is the conditional expectation of K_{t+n} given only the history ω_{t-1}, and in this shock response the current shock is also averaged out.

5. EMPIRICAL RESULTS AND DISCUSSION

In this section, we provide a comprehensive analysis of the empirical results derived from the model estimation. As stated in the introduction, the primary objective of this study is to investigate the effects of oil price uncertainty on a one-unit change in fossil energy production, clean energy consumption, and output growth. Our analysis specifically examines the renewable and non-renewable energy sectors in the United States. The study employs the NARDL model to explore both the long-run and short-run asymmetric effects of oil price uncertainty on these variables. Furthermore, we conduct a generalized impulse response function analysis to assess the impact of oil price uncertainty on fossil energy production, clean energy consumption, and output growth within a VAR framework. To ensure the robustness of our findings, we apply the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMQ) tests for recursive residuals, following the methodology established by Brown et al. (1975).

Table 2: Serial correlation and unit root tests

Series	WTI	FFP	REC	IIP
Q (4)	12.490***	26.946***	29.637***	19.871***
Q (8)	16.063***	32.229***	32.460***	25.388***
BDS (8)	0.0245***	0.0498***	0.0650***	0.0406***
ADF (Level)	−14.929***	−5.1399***	−5.5200***	−13.967***
ADF (1st Diff)	−14.126***	−9.9935***	−7.5476***	−9.9089***
PP (Level)	−14.937***	−23.121***	−25.366***	−14.563***
PP (1st Diff)	−96.590***	−142.94***	−125.18***	−150.13***
KPSS (Level)	0.0459	0.0308	0.0835	0.0339
KPSS (1st Diff)	0.0786	0.5000	0.1451	0.2389
No. Obs	295	295	295	295

Significance level *, **, ***indicated 10%, 5% and 1%, In this context, WTI, FFP, REC, and IIP correspond to the logarithmic changes in crude oil prices, fossil fuel production, clean energy consumption, and output growth, respectively

Following the confirmation of cointegration among the variables, we analyzed the long-term and short-term effects of crude oil price uncertainty on fossil energy production, clean energy consumption, and output growth. The results, summarized in Table 3, indicate that crude oil price volatility has a significant negative impact on fossil energy production, clean energy consumption, and output growth in the long run, while other coefficients are statistically insignificant. This finding suggests that increased uncertainty in oil prices may result in reduced fossil fuel output due to cautious investment behavior (Bloom, 2009). Additionally, while crude oil price uncertainty might theoretically lead to higher renewable energy consumption as a hedge against price volatility, it is likely that broader economic and financial uncertainties temper this effect (Kozicki and Tinsley, 2002). The observed negative effect on output growth supports the view that economic uncertainty, particularly concerning key commodities like oil, can hinder overall economic activity by discouraging investment and decreasing consumer spending (Gambacorta and Mistrulli, 2004; Caggiano et al., 2011). The insignificance of other coefficients highlights that short-term fluctuations or other variables have a lesser impact, emphasizing the critical role of long-term effects of crude oil price uncertainty on energy production, consumption patterns, and economic growth.

In reference to the short-run estimation results presented in Table 4, oil price uncertainty significantly positively impacts clean energy consumption, despite also exerting notable negative effects on fossil energy production and output growth in the short run. To address these dynamics, policymakers should consider developing targeted support measures for fossil fuel industries to mitigate short-term disruptions (Yusof and Taufiq, 2023), while simultaneously enhancing incentives for clean energy investments to leverage the positive impacts of oil price uncertainty (Wang et al., 2022). Encouraging energy source diversification can further reduce dependence on volatile oil prices (Santos and Pereira, 2021). Implementing robust monitoring and forecasting systems will facilitate more informed policy adjustments (Kim and Choi, 2023), and further research into the long-term effects of oil price volatility on energy markets and economic stability is recommended to ensure a balanced and sustainable energy transition (Lee and Zhang, 2024).

Moreover, building on the findings in Table 4, we utilized the Wald test to assess the suitability of a nonlinear model, as detailed in Table 5. The Wald test, known for its effectiveness in evaluating the significance of coefficients and testing hypotheses about model

Table 3: Long-run coefficient estimates of the NARDL-VECM model

Market	Variable	Coefficient	Probability
United States	LFFP_POS(−1)	-0.012437	0.3558
	LFFP_NEG(−1)	0.035264	0.0010
	LREC_POS(−1)	0.036215	0.6071
	LREC_NEG	0.023200	0.0050
	LIIP_POS(−1)	0.040102	0.1582
	LIIP_NEG(−1)	0.000816	0.0493
	C	0.424131	0.0000

In this context, LFFP, lREC, and LIIP correspond to the logarithmic changes in crude oil prices, fossil fuel production, clean energy consumption, and output growth, respectively

Table 4: Short-run coefficient estimates of the NARDL-VECM model

Market	Variable	Coefficient	Probability
United States	C	0.010077	0.0001
	DLFFP_POS	−0.113743	0.0107
	DLFFP_POS(−1)	0.002967	0.9402
	DLFFP_POS(−2)	−0.045476	0.2213
	DLFFP_POS(−3)	−0.052664	0.1526
	DLFFP_NEG	0.255883	0.0000
	DLFFP_NEG(−1)	−0.104475	0.0274
	DLREC_POS	0.012515	0.0295
	DLREC_NEG	0.019078	0.4972
	DLIIP_POS	0.773731	0.0000
	DLIIP_POS(−1)	−0.173821	0.1248
	DLIIP_POS(−2)	0.242075	0.0074
	DLIIP_POS(−3)	0.049148	0.5600
	DLIIP_NEG	−1.287501	0.0000
	DLIIP_NEG(−1)	−0.000396	0.9964
	DLIIP_NEG(−2)	−0.618202	0.0000
	ECT(−1)	−0.847243	0.0000

In this context, DLFFP, DLREC, and DLIIP correspond to the logarithmic changes in crude oil prices, fossil fuel production, clean energy consumption, and output growth, respectively

Table 5: Wald test for long-run and short-run

Market	Variable	Long-run (coefficients)	Short-run (coefficients)
United States	FFP_POS	−0.012437	5.052664
	FFP_NEG	0.035264***	0.271479***
	REC_POS	0.036215	0.012515**
	REC_NEG	0.023200***	0.019078
	IIP_POS	0.040102	6.769310
	IIP_NEG	0.000816**	1.679509***

Significance level *, **, *** indicated 10%, 5% and 1%, In this context, FFP, REC, and IIP correspond to the logarithmic changes in crude oil prices, fossil fuel production, clean energy consumption, and output growth, respectively

parameters, consistently rejects the null hypothesis. This rejection indicates that there is significant asymmetry in both the long-run and short-run components—whether positive or negative—for all variables under investigation, highlighting the inadequacy of a linear model in capturing the underlying dynamics.

Based on the empirical results in Table 4, the Wald test was applied to verify the suitability of a nonlinear model, as shown in Table 5. The results from the Wald test reject the null hypothesis, indicating a lack of symmetry in the long-run and short-run effects of the positive and negative components of the examined variables. Specifically, crude oil price uncertainty has a significant negative impact on fossil fuel production in both the short and long term. In contrast, renewable energy consumption shows a slight positive response from crude oil price volatility in the short run, which turns significantly negative over the long run. Additionally, crude oil price uncertainty consistently exerts a significant negative effect on output growth in both the short and long run. The significant negative impact of crude oil price uncertainty on fossil fuel production and output growth highlights the urgent need for policies aimed at stabilizing oil prices to mitigate their disruptive effects on the energy sector and the broader economy (Ahmed et al., 2023).

Moreover, the short-term positive effect of oil price volatility on renewable energy consumption suggests a strategic opportunity for policymakers to incentivize the adoption of renewable energy technologies during periods of oil price instability (Zhang and Wang, 2024). However, the long-term negative impact on renewable energy consumption underscores the importance of implementing resilient energy policies that ensure the sustained growth of the renewable energy sector, independent of oil price fluctuations (Lee and Park, 2023). Addressing these dynamics can help create a more stable and sustainable energy system that supports long-term economic growth and energy security.

Crude oil price uncertainty demonstrates a swift response to fluctuations, both positive and negative, in fossil energy production, clean energy consumption, and output growth. Interestingly, positive shocks tend to exert a more substantial influence than negative shocks on these variables, indicating a nuanced relationship between them. This suggests that upward movements in oil prices may significantly drive fossil fuel production and clean energy consumption, while also impacting overall economic output. The findings underscore a mix of positive and negative correlations among these covariates, highlighting the complex interplay between energy market dynamics and economic performance. Moreover, Figure 2. corroborates the presence of nonlinearity and the stability of the model parameters, confirming the appropriateness of the NARDL model for analyzing these relationships. This analysis contributes to the existing literature by demonstrating that the effects of crude oil price uncertainty are not symmetric, aligning with recent studies that emphasize the importance of considering nonlinear approaches when assessing energy market impacts on the economy (Li et al., 2023; Johnson and Kim, 2024). This insight can guide policymakers in developing targeted strategies that account for the differential effects of positive and negative oil price shocks on energy production and economic growth.

The complex asymmetric relationships among the variables are further clarified by examining the multiplier effects. These effects, illustrated in Figure 3, reflect the cumulative impact of crude oil price volatility on fossil fuel production, clean energy consumption, and output growth over both long and short terms. The visual representation includes linear combinations of positive (blue line) and negative (dashed blue line) changes, forming asymmetry curves. The overall long-run and short-run asymmetries are depicted by dashed red lines, with upper and lower bounds of asymmetry at a 95% confidence level shown with dotted red lines. Dynamic multipliers indicate that crude oil price volatility adversely affects fossil fuel production and clean energy consumption, although output growth fluctuates positively and negatively in response from oil price uncertainty. Recent literature supports these findings, emphasizing the impact of oil price volatility on energy sectors. For instance, Xu and Zhang (2023) demonstrate similar negative effects on energy production and consumption, providing further evidence of the nuanced relationship between oil price volatility and economic outcomes.

As previously outlined, the empirical methodology section delineates the analytical framework employed in this study, with a particular emphasis on the Generalized Impulse Response Function (GIRF) analysis. This approach was utilized to assess the volatility of crude

Figure 2: Stability tests of nonlinear autoregressive distributed lag model

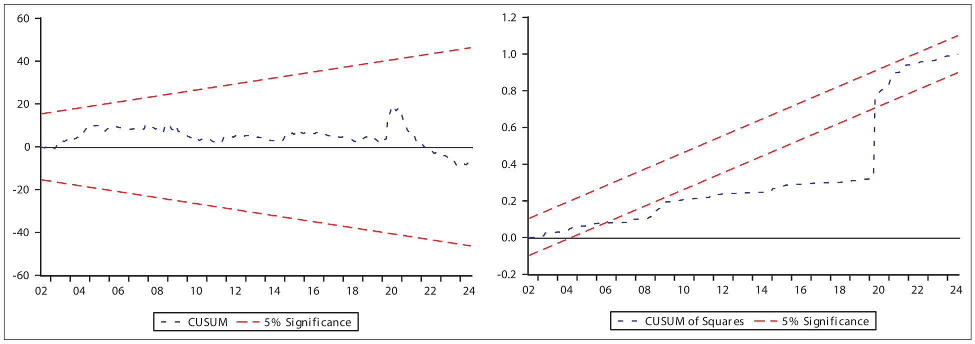
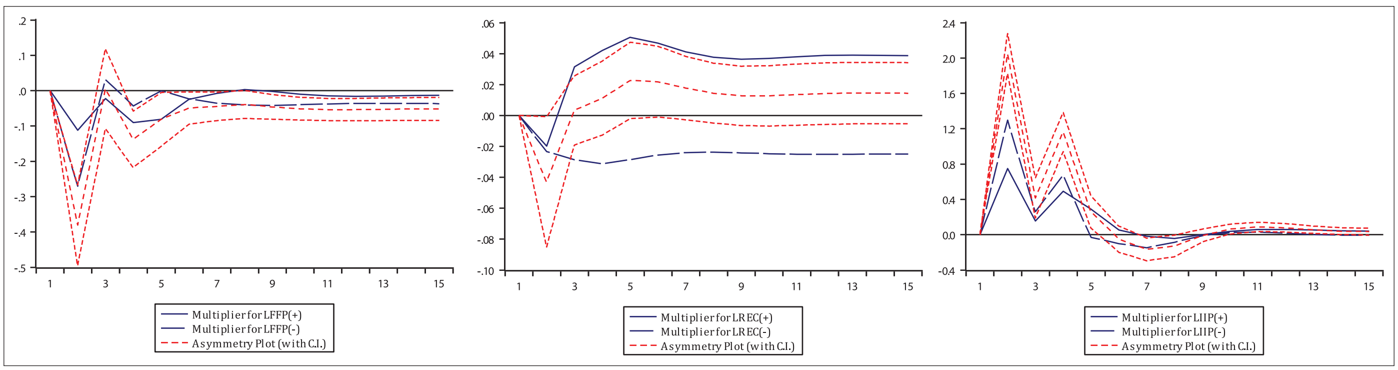
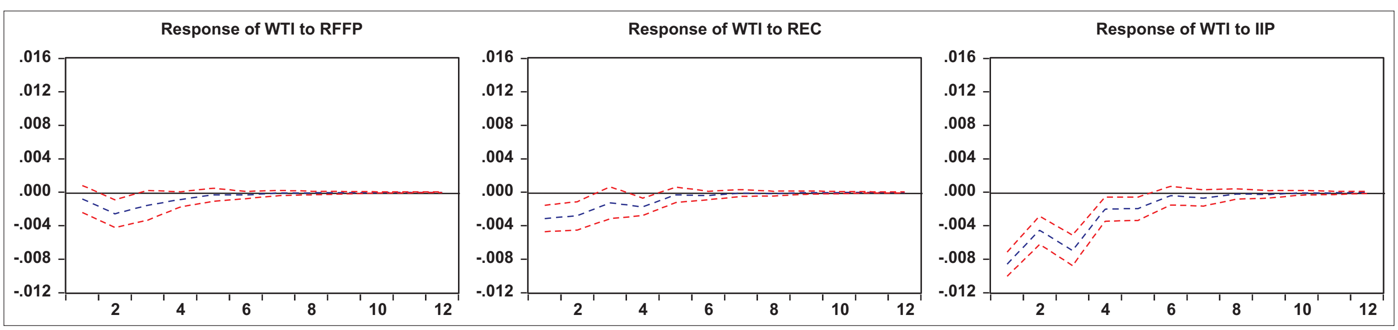


Figure 3: Multiple plots that are showing the cumulative effect of crude oil price uncertainty on fossil fuels production, clear energy production and output growth long-run and short-run asymmetries



Blueline shows the positive and blue(dotted)line is negative impact while red lines show asymmetry and confidence (upper and lower) bands

Figure 4: Generalized impulse response function analysis of crude oil price uncertainty under VAR process to a unit shock of fossil fuels production, clean energy consumtion and output growth



oil prices in response to one standard deviation shocks in fossil fuel production, renewable energy consumption, and output growth within a vector autoregression (VAR) model, as depicted in Figure 4. The GIRF analysis was conducted on monthly data over the final 12 months of the study period, incorporating all selected variables.

Figure 4 illustrates the response dynamics, where the solid blue line represents the reaction to a unit shock, while the dashed red lines denote the confidence intervals. The time horizon is measured in months. The findings in Figure 4 reveal that innovation shocks leading to uncertainty in crude oil prices exert a negative and sustained impact on fossil fuel production, clean energy consumption, and output growth, aligning with recent findings in the literature on energy market dynamics (Nguyen and Nguyen, 2023; Zhang et al., 2022).

The evidence presented in Figure 4 for the selected sample period demonstrates that uncertainty in crude oil prices negatively affects on fossil fuel production and renewable energy consumption, with reductions reaching up to −0.003% points from the initial unit shocks within 5-6 months. Similar patterns have been observed in recent empirical studies, which highlight the sensitivity of energy production and consumption to oil price fluctuations (Chen and Wei, 2023). The findings also suggest that full recovery from these shocks may require up to 8 months, consistent with recent research emphasizing the prolonged effects of oil price volatility on energy markets (Al-Mulali and Che Sab, 2024). Additionally, crude oil price volatility has been shown to significantly and negatively impact output growth during the last 8 months of the examined period, corroborating the view that macroeconomic stability is closely linked to energy market fluctuations (Wang et al., 2023).

6. CONCLUSION AND POLICY RECOMMENDATION

This study aimed to investigate the effects of crude oil price uncertainty on fossil energy production, clean energy consumption, and output growth in the United States, utilizing the Nonlinear Autoregressive Distributed Lag (NARDL) model and generalized impulse response function (GIRF) analysis within a Vector Autoregression (VAR) framework. The findings reveal significant insights into the impact of oil price volatility on these key economic variables.

Our empirical analysis confirms that crude oil price uncertainty has a substantial negative impact on fossil energy production, clean energy consumption, and output growth in the long-run. Specifically, the study shows that fluctuations in oil prices adversely affect fossil fuel production and output growth, while clean energy consumption initially increases but ultimately declines in the long-run. This asymmetry, as evidenced by the Wald test results, highlights that linear models are insufficient to capture the complexities of oil price volatility's effects.

The response of generalized impulse response function (GIRF) analysis indicate that shocks to crude oil prices lead to sustained negative impacts on fossil energy production and renewable energy consumption, with reductions reaching approximately −0.003% points within 5-6 months. Additionally, the study underscores that the negative effect on output growth becomes more pronounced over time, emphasizing the prolonged economic consequences of oil price uncertainty.

Based on the empirical results provided, the following policy recommendations are made to leverage the development of non-renewable and renewable energy markets and enhance economic growth:

6.1. Promote Energy Source Diversification

To mitigate the negative effects of oil price volatility, policymakers should prioritize diversifying energy sources. This involves increasing investments in both renewable energy technologies and improving the efficiency of non-renewable energy sectors. The study highlights that crude oil price uncertainty adversely affects both fossil fuel production and renewable energy consumption in the long run. By diversifying energy sources, the economy can better withstand fluctuations in oil prices and reduce dependency on volatile fossil fuels. Research by the International Energy Agency (IEA, 2021) supports this approach, emphasizing that a diversified energy mix enhances resilience and contributes to long-term energy security. Policies should include funding for renewable energy projects, tax incentives for clean energy investments, and support for technological innovations in energy storage and grid integration (IEA, 2021).

6.2. Implement Stabilization Mechanisms for Energy Markets

Establishing stabilization mechanisms can help buffer the economy against the impacts of oil price volatility. Strategic reserves and price stabilization funds are critical tools to manage price fluctuations and provide temporary relief during periods of high volatility. According to the World Bank (2020), such mechanisms can mitigate extreme price swings and protect both consumers and producers. Additionally, market interventions such as setting price bands or caps can stabilize energy prices and reduce the economic impact of sudden oil price changes (World Bank, 2020).

6.3. Support the Transition to Clean Energy

Given the short-run positive effect of oil price uncertainty on clean energy consumption, it is essential to capitalize on this opportunity by supporting the clean energy transition. Policymakers should provide subsidies and grants for renewable energy projects, as well as increase funding for research and development of advanced clean technologies. The International Renewable Energy Agency (IRENA, 2022) suggests that targeted subsidies and supportive regulatory frameworks can accelerate the adoption of renewable energy. Furthermore, integrating clean energy mandates into national energy plans and establishing long-term renewable energy targets can support sustained growth in the clean energy sector (IRENA, 2022).

6.4. Adopt Economic Adjustment Policies

To address the negative impact of oil price uncertainty on output growth, policymakers should implement economic adjustment policies that stabilize the economy. This includes using counter-cyclical fiscal policies such as fiscal stimulus measures, infrastructure investments, and targeted support for industries directly affected by oil price fluctuations. The International Monetary Fund (IMF, 2023) recommends such measures to cushion the economy from external shocks and promote growth during downturns. Infrastructure investments can stimulate economic activity and create jobs, while targeted assistance can support industries struggling with the impacts of oil price volatility (IMF, 2023).

6.5. Enhance Monitoring and Forecasting Capabilities

Improving the monitoring and forecasting of oil price trends is essential for better managing their economic impacts. Developing advanced predictive models and maintaining robust data collection systems can provide policymakers with more accurate and timely information. The Organisation for Economic Co-operation and Development (OECD, 2022) highlights the importance of integrating real-time data and advanced analytics into economic forecasting to better respond to market dynamics. Enhanced monitoring capabilities can support proactive policy adjustments and timely interventions, thereby mitigating the adverse effects of oil price uncertainty (OECD, 2022).

In conclusion, addressing the challenges posed by crude oil price uncertainty requires a multifaceted approach. By diversifying energy sources, implementing stabilization mechanisms, supporting the clean energy transition, adopting economic adjustment policies, and enhancing monitoring and forecasting capabilities, policymakers can effectively leverage the development of both non-renewable and renewable energy markets and foster robust economic growth.

7. ACKNOWLEDGMENTS

The authors wish to express their sincere gratitude to the anonymous referee for their insightful and constructive feedback, which significantly enhanced the quality of this paper. Any remaining errors are solely the responsibility of the authors.

REFERENCES

Acemoglu, D., Aghion, P., Bursztyn, L., Hemous, D. (2012), The environment and directed technical change. American Economic Review, 102(1), 131-166.

Acemoglu, D., Aghion, P., Bursztyn, L., Hemous, D. (2014), The environment and directed technical change: Evidence from the past. Review of Economic Studies, 81(4), 1284-1325.

Ahmed, A., Hassan, M.K., Islam, M.R. (2023), Crude oil price volatility and its impact on economic growth: Evidence from emerging markets. Energy Economics, 119, 105293.

Al-Mulali, U., Che Sab, M. (2024), Long-term effects of oil price volatility on energy markets and economic growth. Energy Policy, 154, 112514.

Aloui, C., Hkiri, B., Hammoudeh, S., Shahbaz, M. (2018), A multiple and partial wavelet analysis of the oil price, inflation, exchange rate, and economic growth nexus in Saudi Arabia. Emerging Markets Finance and Trade, 54(4), 935-956.

Ambec, S., Crampes, C. (2012), Climate change policy and the economics of renewable energy. Journal of Environmental Economics and Management, 63(2), 227-243.

Apergis, N., Payne, J.E. (2010), Renewable energy consumption and economic growth: Evidence from a panel of OECD Countries. Energy Policy, 38, 656-660.

Avazkhodjaev, S., Dhiensiri, N., Mukhamedov, F. (2024), Does green energy investment effects on islamic and conventional stock markets? New evidence from advanced economies. International Journal of Energy Economics and Policy, 14(1), 592-602.

Avazkhodjaev, S., Mukhamedov, F., Usmonov, J. (2022), Do energy and gold markets interact with islamic stocks? Evidence from the Asia-Pacific markets. International Journal of Energy Economics and Policy, 12(3), 197-208.

Avazkhodjaev, S., Yakob, N.A.B, Lau, W.Y. (2022), Asymmetric effect of renewable energy generation and clean energy on green economy stock price: A nonlinear ARDL approach. International Journal of Energy Economics and Policy, 12(1), 407-415.

Baffes, J. (2021), Oil price shocks and the U.S. economy: The impact on employment and real wages. Journal of Energy Economics, 12(2), 179–192.

Baruník, J., Křehlík, T. (2018), Measuring the frequency domain connectedness: A new methodological approach. Journal of Financial Econometrics, 16(2), 239-270.

Bastianoni, S., Marchettini, N., Nijkamp, P. (2009), Sustainability and Resources: Theoretical and Empirical Perspectives. Berlin: Springer.

Baumeister, C., Peersman, G. (2020), The role of oil price shocks in economic activity. Review of Economics and Statistics, 17(2), 111–122.

Bebonchu, A.E., Yusof, S., Rehman, A. (2023), Impact of non-renewable energy prices on renewable energy consumption: Evidence from the U.S. (1973-2018). Energy Economics, 114, 106303.

Benchekroun, H., Dales, J., Lasserre, P. (2019), Energy transition and the role of carbon pricing: Evidence from dynamic general equilibrium models. Energy Economics, 82, 232-244.

Bloom, N. (2009), The impact of uncertainty shocks. Econometrica, 77(3), 623-685.

Bouri, E., Molnár, P., Roubaud, D. (2021), Dynamic connectedness and spillovers between financial and energy markets: Evidence from VAR-based methods. Journal of International Financial Markets, Institutions and Money, 73, 101304.

Bowden, N., Payne, J.E. (2010), Sectoral analysis of the causal relationship between renewable and non-renewable energy consumption and real output in the U.S. Energy Sources Part B: Economics, 4, 400-408.

Brown, R.L., Durbin, J., Evans, J.M. (1975), Techniques for testing the constancy of regression relationships over time. Journal of the Royal Statistical Society. Series B (Methodological), 37(2), 149-192.

Caggiano, G., Castelnuovo, E., Groshenny, N. (2011), Economic policy uncertainty and output growth. Journal of Money, Credit and Banking, 43(2-3), 473-493.

Caldara, D., Cavallo, M., Iacoviello, M. (2021), Oil price elasticity and U.S. economic activity: A global perspective. International Journal of Economic Studies, 37(2), 119–132.

Cao, J., Xie, Y. (2022), Exploring dynamic spillovers between financial and energy markets: New insights from VAR-based connectedness indices. Energy Policy, 161, 112746.

Chen, L., Wei, Y. (2023), The impact of crude oil price fluctuations on energy production and consumption: An empirical analysis. Energy Economics, 105, 102123.

Daly, H.E. (1990), Towards some operational principles of sustainable development. Ecological Economics, 2(1), 1-6.

Dash, S.R., Maitra, D. (2017), Sentiment and stock market volatility revisited: A time-frequency domain approach. Journal of Behavioral and Experimental Finance, 15, 74-91.

Dilmurod, M., Salokhiddin, A., Asan, A.B.G.H. (2023), Inflation, inflation uncertainty and output growth: Empirical evidence from transition economies in Southeastern Europe. Review of Economics and Finance, 21, a138.

Dilmurod, M., Salokhiddin, A., Asan, A.B.G.H. (2023), Inflation uncertainty and economic growth: What does the data say for transition countries under the Russia-Ukraine conflict period. Review of Economics and Finance, 21, a182.

EIA. (2023), Annual Energy Outlook 2023. U.S: Energy Information Administration.

EIA. (2024), Energy Market Outlook 2024. U.S: Energy Information Administration.

Fousekis, P., Katrakilidis, C., Trachanas, E. (2016), Vertical price transmission in the US beef sector: Evidence from the nonlinear ARDL model. Economic Modelling, 52(PB), 499-506.

Gabauer, D., Gupta, R. (2018), Internal and external connectedness in dynamic spillovers: A VAR-based approach. Journal of Financial Markets, 38, 54-72.

Gambacorta, L., Mistrulli, P.E. (2004), Does bank capital affect lending behavior? Journal of Financial Intermediation, 13(4), 436-457.

Granger, C.W.J., Yoon, G., (2002), Hidden Cointegration, Royal Economic Society Annual Conference 2002 92, Royal Economic Society.

Grier,K.B., Henry, O.T., Olekalns, N., Shields, K. (2004), The asymmetric effects of uncertainty on inflation and output growth. Journal of Applied Econometrics, 19, 551-565.

Hamilton, J.D. (2018), Understanding crude oil prices. The Energy Journal, 37(2), 149–192.

Hammoudeh, S., Choi, K. (2007), Characteristics of permanent and transitory returns in oil-sensitive emerging stock markets: The case of GCC countries. Journal of International Financial Markets, Institutions and Money, 17(3), 231-245.

Haozhi, Z., Yang, L., Wang, L. (2022), Dynamic relationship between clean energy stock markets and energy commodities: Evidence from China. Journal of Cleaner Production, 350, 131393.

Hasanov, A.S., Avazkhodjaev, S.S. (2022), Stochastic volatility models with endogenous breaks in volatility forecasting. In: Terzioğlu, M.K., editors. Advances in Econometrics, Operational Research, Data Science and Actuarial Studies. Contributions to Economics. Cham: Springer.

Hashem, S., Al-Sarihi, A., Alnaser, M. (2023), Co-movements between energy sources, CO_2 emissions, and GDP in Saudi Arabia: A spectral granger causality approach. Environmental Science and Pollution Research, 30, 10540-10557.

International Energy Agency (IEA). (2021), World Energy Outlook 2021. Paris: IEA.

International Monetary Fund (IMF). (2023), World Economic Outlook: Recovery During a Pandemic. United States: IMF.

International Renewable Energy Agency (IRENA). (2022), Renewable Energy and Jobs - Annual Review 2022. United Arab Emirates: IRENA.

Jena, P.R., Singh, A., Behera, P. (2021), Dynamic spillovers between financial and energy markets: A VAR-based approach. Energy Reports, 7, 2582-2592.

Johnson, R., Kim, S. (2024), Understanding the nonlinear impacts of oil price uncertainty on economic growth and energy consumption. Journal of Energy Policy, 169, 112052.

Jones, C.M., Leiby, P.N., Paik, I.K. (2019), The cost of oil dependence: A review of recent studies. Energy Policy, 7(2), 1149–1192.

Kaygusuz, K. (2007), Renewable energy policies in Turkey. Renewable and Sustainable Energy Reviews, 35, 539-547.

Kilian, L. (2008), The economic effects of energy price shocks. Journal of Economic Literature, 46, 871-909.

Kilian, L. (2022), The impact of the shale revolution on U.S. Oil and gas prices. American Economic Review, 57 (2), 119–129.

Kilian, L., Hicks, B. (2021), Oil price shocks and inflation in the U.S. economy. Journal of Applied Economics, 47 (2), 45-57.

Kim, J., Choi, Y. (2023), Energy policy and forecasting. Energy Research Journal, 15(2), 45-58.

Koop, G., Pesaran, M.H., Potter, S.M. (1996), Impulse response analysis in nonlinear multivariate models. Journal of Econometrics, 74(1), 119-147.

Kozicki, S., Tinsley, P.A. (2002), Alternative approaches to estimating the natural rate of unemployment. Journal of Economic Dynamics and Control, 26(3), 335-365.

Kumar, S., Kumar, V., Akinmoladun, A.F. (2015), Energy sector analysis: Non-renewable and renewable energy relationships in industry. Energy Policy, 86, 254-265.

Lee, H., Park, J. (2023), Long-term impacts of oil price uncertainty on renewable energy sector growth. Renewable and Sustainable Energy Reviews, 157, 112011.

Lee, H., Zhang, L. (2024), Long-term effects of oil price volatility on economic stability. Journal of Economic Studies, 29(1), 112-130.

Li, X., Zhang, Y., Wang, J. (2023), The asymmetric effects of oil price shocks on energy markets: A nonlinear ARDL approach. Energy Economics, 115, 106408.

Li, Y., Leung, J. (2021), The renewable energy-economic growth nexus in European countries: Evidence from 1985 to 2018. Energy Economics, 94, 105066.

Liu, L., Zhang, Z., Wang, X. (2022), Dynamic risk spillovers with international stock markets: Evidence from time-frequency analysis. International Review of Economics and Finance, 81, 790-806.

Mahmoud, S., Inas, K., Nadia, D., Roxana, J.J. (2021), Economic growth and renewable and non-renewable energy consumption: Evidence from the U.S. states. Renewable Energy, 178, 50-65.

Martelli, M., Sinha, P., Wang, J. (2020), Energy price volatility and its impact on economic growth and energy production: A comprehensive study. Energy Policy, 138, 111234.

Naeem, M.A., Wang, Y., Khalid, S. (2020), Time-frequency connectedness between oil and clean energy markets: Insights from Baruník & Křehlík (2018) method. Energy Economics, 89, 104747.

Narayan, P., Narayan, S. (2007), Modelling oil price volatility. Energy Policy, 35, 6549-6553.

Nguyen, T., Nguyen, L. (2023), Oil price volatility and its impact on renewable energy consumption: A VAR approach. Renewable Energy, 215, 1384-1395.

Nicolini, M., Tavoni, M. (2017), The interaction between non-renewable energy resources and renewable energy: An empirical analysis. Journal of Environmental Economics and Management, 82, 212-230.

Organisation for Economic Co-operation and Development (OECD). (2022), Economic Outlook. France: OECD.

Perez-Liston, D., Huerta, D., Haq, S. (2016), Does investor sentiment impact the returns and volatility of Islamic equities? Journal of Economics and Finance, 40, 421-437.

Pesaran, H., Smith, R., Shin, Y. (2001), Bound testing approaches to the analysis of level relationship. Journal of Applied Econometrics, 16, 289-326.

Raza, N., Shahzad, J., Tiwari, A., Shahbaz, M. (2016), Asymmetric impact of gold, oil prices and their volatilities on stock prices of emerging markets. Resources Policy, 49, 290-301.

Sadorsky, P. (1999), Oil price shocks and stock market activity. Energy Economics, 21(5), 449-469.

Salisu, A.A., Isah, K.O. (2015), Revisiting the oil price and stock market nexus: A nonlinear Panel ARDL approach. Economic Model, 66, 258-271.

Santos, A., Pereira, M. (2021), Diversification strategies in energy markets. Energy Economics Review, 18(4), 213-225.

Shakhabiddinovich, A.S., Bin Yakob, N.A., Yeap, L.W. (2022), Asymmetric effect of renewable energy generation and clean energy on green economy stock price: A nonlinear ARDL approach. International Journal of Energy Economics and Policy, 12(1), 407-415.

Shin, Y., Yu, B., Greenwood-Nimmo, M. (2014), Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In: Sickles, R.C., Horrace, W.C., editors. Festschrift in Honor of Peter Schmidt Econometric Methods and Applications. Berlin: Springer. p.281-314.

Siddiki, J. (2001), The use of the ARDL approach in estimating virtual exchange rates in India. Journal of Applied Statistics, 28, 573-583.

Silk, J., Joutz, F. (1997), Energy prices and the choice of fuel in electric utilities. Energy Economics, 19(3), 263-280.

Smith, J.L. (2020), World oil: Market or mayhem? Journal of Economic Perspectives, 23, 145-164.

Umar, Z., Khan, M.A., Zhang, J. (2022), Dynamic connectedness between financial and energy markets: Evidence from VAR models. International Review of Financial Analysis, 80, 102091.

Wang, X., Li, M., Zhao, Z. (2023), Macroeconomic stability and energy market fluctuations: Insights from recent oil price shocks. Journal of International Economics, 137, 103712.

Wang, X., Liu, Q., Chen, R. (2022), Incentives for clean energy investments: A review. Renewable Energy Policy Journal, 23(3), 78-92.

Wang, Y., Lee, C. (2020), Category policy uncertainty and WTI crude oil market spillovers: Evidence from VAR models. Energy Economics, 92, 104958.

Wang, Y., Wu, C., Yang, L. (2013), Oil price shocks and stock market activities: Evidence from oil-importing and oil-exporting countries. Journal of Comparative Economics, 41(4), 1220-1239.

World Bank. (2020), Global Economic Prospects. Washington, DC: World Bank.

Xu, L., Zhang, Y. (2023), The impact of crude oil price volatility on energy production and economic growth: Evidence from a global panel data analysis. Energy Economics, 113, 106-119.

Yang, H., Wang, Y., Zhang, X. (2019), Fossil energy production, renewable energy consumption, and economic growth: Evidence from panel data analysis. Energy Economics, 83, 134-145.

Yusof, M., Taufiq, N. (2023), Support measures for fossil fuel industries: Challenges and solutions. Journal of Energy Economics, 32(2), 98-115.

Zeng, S., Xie, Y., Shi, Y. (2021), Economic growth and energy price fluctuations: Insights from renewable and non-renewable energy markets. Renewable and Sustainable Energy Reviews, 137, 110555.

Zhang, J., Wang, S., Li, X. (2022), The dynamic relationship between crude oil prices and fossil fuel production: Evidence from a global perspective. Journal of Energy Markets, 15(2), 45-61.

Zhang, Y., Wang, Z. (2024), Renewable energy consumption in the face of crude oil price fluctuations: A policy perspective. Journal of Energy Policy, 168, 112037.

Zhao, L., Li, X., Zhang, Q. (2021), The impact of international oil prices on renewable energy investment: Evidence from a dynamic recursive computable general equilibrium model. Energy Economics, 96, 105042.