Management Strategies and Engineering Sciences 2025; 7(3):91-100

The Effects of Oil Price Volatility and Trade Intensity on Renewable Energy Consumption in Oil-Importing Countries

Fatemeh Eghbal Manesh[1], Shahriar Nesabian[2*] Mahmood Mahmoodzadeh[3] Alireza Daghighi Asli[4]

[1] Department of Oil and Gas Economics, Central Tehran Branch, Islamic Azad University, Tehran, Iran.
[2] Department of Economics, Central Tehran Branch, Islamic Azad University, Tehran, Iran.
[3] Department of Economics, Firuzkooh Branch, Islamic Azad University, Firuzkooh, Iran (Corresponding Author).
[4] Department of Economics, Central Tehran Branch, Islamic Azad University, Tehran, Iran.

*** Corresponding author email address**: ma.mahmod@yahoo.com

Received: 2024-11-11 **Reviewed:** 2024-12-16 **Revised:** 2025-01-20 **Accepted:** 2025-02-22 **Published:** 2025-06-30

Abstract

The expansion of renewable energy consumption has received special attention due to the increasing limitations of natural resources. This study examines the impact of oil price volatility and trade intensity on renewable energy consumption in oil-importing countries. Accordingly, data from ten major oil-importing countries, including the United States, Japan, China, Germany, the Netherlands, South Korea, Italy, India, France, and Singapore, covering the years 2000 to 2022, have been analyzed. In this study, oil price volatility was measured using the EGARCH method, and the estimation results of the model and relationships between variables were analyzed within the framework of the generalized method of moments (GMM). The results indicate that oil price volatility, with a coefficient of 1.27, trade intensity, with a coefficient of 0.30, innovation, with a coefficient of 0.97, and human capital development, with a coefficient of 0.42, contribute to the increase in renewable energy consumption.

Keywords: *Oil price, trade development, renewable energy, innovation*.

How to cite this article:

Eghbal Manesh, F., Nesabian, Sh., Mahmoodzadeh, M., Daghighi Asli, A. (2025). The Effects of Oil Price Volatility and Trade Intensity on Renewable Energy Consumption in Oil-Importing Countries. Management Strategies and Engineering Sciences, 7(3), 91-100.

1. Introduction

The deterioration of environmental quality and the intensification of climate change adversities worldwide have generally led to a consensus on aligning global development policies with the simultaneous preservation of environmental characteristics. In the past, the notion of "economic growth now and environmental cleanup later" was accepted, thereby acknowledging the trade-off between economic and environmental well-being. However, contemporary development policies primarily focus on greening global production processes, particularly to curb greenhouse gas emissions resulting from the dominant combustion of fossil fuels. Thus, it is imperative for the global economy to transition from the use of non-renewable energy sources to renewable energy sources while maintaining environmental sustainability as a key consideration [1-3].

In this regard, the United Nations Sustainable Development Goals (SDGs) agenda also calls for global commitments to increase renewable energy resources in global energy portfolios to ensure energy security and environmental sustainability across the planet. The seventh of the seventeen Sustainable Development Goals specifically emphasizes a significant increase in the share of renewable energy in global energy consumption figures by the end of 2030 [4]. Consequently, global economies have outlined their commitments toward achieving the SDGs within this designated timeframe. The benefits of increasing renewable energy consumption in the economy can take multidimensional forms. For instance, incorporating renewable energy technologies into national energy policies worldwide is likely to complement global energy security strategies, which appear to be at risk due to the depletion of global non-renewable energy reserves [5].

Therefore, the expansion of renewable energy in the global energy mix not only alleviates pressures from global fossil fuel demand but also complements non-renewable energy reserves by significantly enhancing the overall reliability of energy resources [6]. Furthermore, the volume of renewable energy consumption can play a pivotal role in mitigating greenhouse gas emission intensity. This, in turn, is attributed to improving environmental quality while simultaneously reducing the pace of climate change [7]. The increased level of renewable energy consumption was also duly endorsed at the Paris Climate Change Conference in 2015, recognizing its decisive role in keeping the rise in global temperature below the critical threshold of 2 degrees Celsius per year, which is largely deemed appropriate for combating climate change adversities [8, 9].

Among other positive effects, the hypothesis of increased renewable energy consumption suggests reduced economic vulnerability to exogenous fluctuations in crude oil sources [10], stabilization of energy prices [11], enhanced energy consumption efficiency [2], increased electricity access rates [12], improvements in rural electrification [13], facilitation of off-grid electrification [14], and the creation of employment opportunities in local communities [15, 16].

Oil is one of the most significant macroeconomic factors in the global economy, and the economic performance of countries is highly correlated with oil prices. Compared to other internationally traded commodities, oil can be considered the only production input that can exert both positive and negative effects on economic growth and may even lead to drastic changes in the economy. Depending on the type of economy, fluctuations in oil prices can have either negative or positive effects on economic stability. Some empirical studies conclude that oil prices negatively impact economic growth in various countries [10, 17-38]. On the other hand, several studies [18, 21, 23, 31, 39] support the positive relationship between crude oil prices and economic growth. In developing countries, oil prices not only negatively impact economic growth but also have greater effects on household consumption balances, poor farmers in rural areas, and transportation in urban regions [29]. Regarding unemployment, in such countries, due to high production costs leading to increased input costs and subsequently higher unemployment rates, the impact is also considered positive [17].

Various factors influence renewable energy consumption. One such factor is the human capital development index, which, in turn, affects other variables such as innovation. The Human Development Index (HDI) is one of the most relevant indicators considered by several international organizations to assess the development status of countries. It encompasses and analyzes multiple variables in education, health, income, and living standards to comprehensively develop a summary measure that incorporates all these elements and explains the welfare conditions of individuals in a country. The average HDI levels have continuously increased since 1990—by 22% globally and by 51% in less developed countries. This index not only provides clear insights into a country's development but also offers information regarding government policy priorities [40].

The transition from non-renewable to renewable energy sources has been a critical area of research in recent years, particularly in relation to economic growth, environmental sustainability, and policy implications. Mohsin et al. (2021) analyzed the impact of shifting from non-renewable to renewable energy consumption on the economic growth-environment nexus in developing Asian economies, finding that while economic growth and energy consumption are positively correlated, a 1% increase in renewable energy consumption reduces carbon emissions by 0.193%. Their study underscores the significant role of renewable energy in mitigating greenhouse gas emissions and highlights the need for stronger regional environmental policies [41]. In a related study, Adebayo et al. (2021) examined the asymmetric effects of renewable energy consumption and trade openness on carbon emissions in Sweden, demonstrating that renewable energy consumption significantly reduces environmental degradation. They advocate for greater public awareness to promote the adoption of renewable energy [42]. Similarly, Alvarado et al. (2021) investigated whether economic development and human capital contribute to the reduction of non-renewable energy consumption in OECD countries. Their findings indicate that while economic development alone does not guarantee a decline in fossil fuel consumption, human capital and globalization are crucial drivers of the transition to a more sustainable energy matrix [43]. Collectively, these studies highlight the intricate relationship between energy consumption, economic growth, environmental sustainability, financial development, and oil market volatility, emphasizing the importance of comprehensive policies to ensure a sustainable transition to renewable energy sources.

This study seeks to answer the question of how oil prices and trade intensity influence renewable energy consumption, considering the mediating role of innovation and human capital development.

2. Methodology

This study employs an analytical approach based on its subject and objectives, utilizing a panel data method in terms of research design and implementation. The statistical population comprises ten major oil-importing countries, including the United States, Japan, China, Germany, the Netherlands, South Korea, Italy, India, France, and Singapore, covering the years 2000 to 2022. Initially, oil price volatility is calculated using the EGARCH method, followed by estimating the model and analyzing the relationships between variables within the framework of the generalized method of moments (GMM).

The research model, with slight modifications, is based on the model by Amiri & Nguyen (2019) and is formulated as follows:

$$RE_{it} = \beta_0 + \beta_1 Oilp_{it} + \beta_2 Develop_{it} + \beta_3 Inno_{it} + \beta_4 Hdi_{it} + \varepsilon_{it}$$

Where:

RE: Renewable Energy. This variable is measured using the renewable energy consumption index, sourced from the database available at www.EIA.ORG.

Oilp: Oil Price. This variable is measured using Brent oil prices available from the BP database.

Develop: Trade Intensity. This variable is measured by the ratio of imports plus exports to gross domestic product (GDP), obtained from the World Bank database at worldbank.org.

Inno: Global Innovation Index. This variable is measured using technological innovation data extracted from the World Bank database at worldbank.org.

Hdi: Human Development Index (HDI). This index is one of the most relevant indicators used by several international organizations to assess the development status of countries. HDI provides a single index representing three key dimensions of human development: a long and healthy life, access to knowledge, and a decent standard of living. Data for this variable are obtained from the Human Development Reports website at undp.org.

2.1. GARCH Model

The GARCH model was introduced in 1986. The simplest form of this model is as follows:

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta\sigma_{t-1}^2$$

This model is denoted as GARCH(1,1), indicating that residuals are considered with one lag and conditional variance is also included with one lag. If the variance is rewritten with lags and substituted into this equation, we obtain:

$$\sigma_t^2 = \alpha_0' + \alpha_1' u_{t-1}^2 + \alpha_2' u_{t-2}^2 + \alpha_3' u_{t-3}^2 + \dots$$

Where:

$$\alpha_0' = \alpha_0 \sum_{i=0}^{\infty} \beta^i$$

$$\alpha_i' = \alpha_1 \beta^i$$

Thus, the above model is equivalent to ARCH(∞). The general form of GARCH(p,q) is given by:

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \dots + \alpha_q u_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + \dots + \beta_p \sigma_{t-p}^2$$

$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i u_{t-i}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2 + V_t$

This equation consists of three main components:

α_0: Represents the constant term.

u_{t-i}^2: Represents the ARCH term, which reflects past period volatility information and is calculated using lagged squared residuals from the mean equation.

σ_{t-j}^2: Represents the GARCH term, which accounts for past period variance.

2.2. EGARCH Model

The exponential GARCH (EGARCH) model was proposed by Nelson (1991). In this model, conditional variances are formulated differently. The conditional variance in the exponential GARCH model is computed as follows (Nelson, 1991):

$$\ln(\sigma_t^2) = \omega + \beta \ln(\sigma_{t-1}^2) + \gamma \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha \left[\frac{|u_{t-1}|}{\sqrt{\sigma_{t-1}^2}} - \sqrt{2/\pi}\right]$$

This model has several advantages. First, in this model, the dependent variable (σ_t^2) is logarithmic, allowing the coefficients of the right-hand side variables to be either positive or negative while ensuring that σ_t^2 remains positive. Consequently, there is no need to impose the non-negativity restriction on coefficients. Second, if the impact of shocks is asymmetric, this model accounts for them. The coefficient γ represents the asymmetry of shocks, as u_{t-1} can be either positive or negative. If γ equals zero, symmetry exists; otherwise, asymmetry is confirmed. A positive γ indicates that negative shocks have a greater impact than positive shocks. In other words, the impact of positive shocks equals γ, while the impact of negative shocks equals $\gamma + \alpha$ (Souri, 2011).

2.3. Generalized Method of Moments (GMM)

When the dependent variable appears with a lag on the right-hand side in a panel data model, ordinary least squares (OLS) estimators are no longer appropriate (Hsiao, Arellano & Bond, and Baltagi, 1995). One of the key applications of panel data is to help researchers better understand dynamic relationships. Dynamic relationships are modeled by including lagged dependent variables among explanatory variables:

$$y_{it} = \delta y_{i,t-1} + x_{it} \beta + \mu_i + \varepsilon_{it}$$

where δ and β are scalars.

Assuming that μ_i follows a one-sided error component model, meaning only one factor causes cross-sectional differences (fixed effects pattern), we have:

$$y_{it} - y_{i,t-1} = \delta(y_{i,t-1} - y_{i,t-2}) + (x_{it} - x_{i,t-1})\beta + (\varepsilon_{it} - \varepsilon_{i,t-1})$$

where μ_i is uncorrelated across sections.

Autocorrelation arises due to the presence of a lagged dependent variable among explanatory variables and cross-sectional heterogeneity across sections. Since μ_i is a function of $y_{i,t-1}$, it is clear that $y_{i,t-1}$ is correlated with the error term. Consequently, $y_{i,t-1}$, as an explanatory variable, is correlated with the error term, causing the OLS estimator to be biased and inconsistent. Even if ε_{it} is not serially correlated, the GLS estimator is also biased under the assumption of random effects in dynamic panel data models (Abrashemi et al., 2009).

Given the dynamic nature of the model in this study, where the variable y appears with a lag on the right-hand side of the equation, we use a dynamic panel data estimation approach. Therefore, it is necessary to resort to two-stage least squares (2SLS) estimation by Anderson & Hsiao (1981) or GMM estimation by Arellano & Bond (1992). According to Matthias & Suster, the 2SLS method may yield large variance estimates for coefficients due to difficulties in selecting instruments, making the estimates statistically insignificant. Hence, Arellano & Bond proposed the GMM method to address this issue.

In the generalized method of moments (GMM), to eliminate the correlation between the lagged dependent variable and the error term, lagged values of the variables are used as instruments in two-step GMM estimation. Additionally, since the consistency of the GMM estimator depends on the validity of the instruments used, the Sargan test, as suggested by Arellano & Bond, Blundell & Bond, and Arellano & Bover, is employed to assess this validity. The Sargan test evaluates the overall validity of the instruments, with the null hypothesis stating that the instruments are uncorrelated with the error term.

3. Findings and Results

This section first examines the stationarity of the research variables, estimates oil price volatility, and then conducts a cointegration test. Subsequently, autocorrelation tests are performed, and finally, the model estimation results are presented based on the hypotheses.

In theory, these tests are multiple-unit root tests used for panel data structures. In these tests, the stationarity verification process, except for the Hardy method, follows a similar approach, where rejecting the null hypothesis indicates stationarity of the variable. Thus, the null hypothesis is rejected, and stationarity is accepted (Bahrami et al., 2013). To assess the collective stationarity of the variables, four tests were employed: Levin, Lin & Chu, Im, Pesaran & Shin, Fisher-Augmented Dickey-Fuller (ADF), and Fisher-Phillips-Perron.

Table 1. Results of the Panel Unit Root Test for Model Variables

Variable	PP-Fisher Statistic	Probability	ADF-Fisher Statistic	Probability	Im, Pesaran and Shin Statistic	Probability	Levin, Lin & Chu Statistic	Probability
RE (level)	17.65	0.00	53.83	0.00	-4.53	0.00	-10.67	0.00
Oilp (level)	84.75	0.00	73.86	0.00	-3.22	0.00	-7.87	0.00
Develop (level)	74.95	0.00	75.14	0.00	-3.82	0.00	-6.77	0.00
Inno (level)	25.03	0.86	30.63	0.63	-0.007	0.49	-2.86	0.00
Hdi (level)	20.96	0.96	21.59	0.95	1.07	0.85	-1.82	0.00

The results of the above table indicate that all variables are stationary at the level. In the next step, the presence of long-term economic relationships is tested using the panel cointegration test.

The fundamental idea of cointegration analysis is that although many economic time series are non-stationary, a linear combination of these variables may be stationary in the long run. Cointegration analysis helps test long-term equilibrium relationships. Several tests are available for panel data cointegration analysis, such as Kao, Pedroni, and Fisher tests. In this study, the Kao test is used, as the Pedroni test is infeasible due to the large number of model variables, and the Fisher test is not applicable due to insufficient data.

Table 2. Cointegration Test Among Research Variables

Cointegration Kao	t-Statistic	P-Value
ADF	-3.43	0.00

According to the above table, the Kao test confirms the existence of cointegration at a 99% confidence level, indicating a long-term equilibrium relationship and ruling out spurious regression.

Initially, the optimal lag length is determined using the Schwarz criterion. The VAR model is estimated for oil prices, and the Schwarz values for different lags are obtained using the lag length criteria. The lag with the lowest Schwarz statistic is considered the optimal lag, as shown in the following table.

Table 3. Determining the Optimal Lag Length for Oil Prices

Lag	Schwarz Criterion (SC)
0	6.25
1	5.73
2	5.78
3	6.90
4	7.20
5	7.38

As observed in Table 3, the lowest Schwarz criterion value corresponds to the first lag. Thus, considering the optimal lag, the following model is estimated for the mean equation of oil prices using the ordinary least squares (OLS) method:

$$\pi_t = \alpha_0 + \alpha_1 \pi_{(t-1)} + \varepsilon_t$$

After estimating the model for the mean equation of oil prices, goodness-of-fit tests are conducted.

a. Autocorrelation Test for Residuals

The Breusch-Godfrey test is used to check for the presence or absence of autocorrelation in the error terms. The results are presented in the following table.

Table 4. Breusch-Godfrey Test Results

Variable	Intercept	Trend	Test Statistic	P-Value	Result
Residual	-	+	0.92	0.34	Acceptance of H_0

As shown in the table above, the null hypothesis of no serial correlation is accepted, indicating that the mean equation model for oil prices is free from autocorrelation.

b. Estimating Oil Price Uncertainty

Considering EGARCH(1,1) as the criterion for estimating oil price uncertainty, the time series of oil price uncertainty is estimated using the following model:

LOG(GARCH) = C(3) + C(4) * ABS(RESID(-1) / @SQRT(GARCH(-1))) + C(0) * RESID(-1) / @SQRT(GARCH(-1)) + C(6) * LOG(GARCH(-1))

Next, uncertainty forecasting is performed using the EGARCH(1,1) model, where the conditional variance of oil prices is used as a proxy for oil price uncertainty.

After estimating oil price uncertainty, the next step is to test the absence of heteroscedasticity in the residuals of the EGARCH(1,1) model. To this end, the LM-ARCH test is used to examine variance heteroscedasticity in the residuals. The following table presents the test results.

Table 5. Results of the Variance Heteroscedasticity Test

Test Statistic	Statistical Value	Probability
F-Statistic	0.364	0.579
R-squared x Number of Observations	0.37	0.70

The results in Table 5 indicate that the null hypothesis of the LM test, which states that there is no heteroscedasticity, cannot be rejected. Therefore, the residuals of the estimated model for oil price uncertainty do not suffer from heteroscedasticity and can be used as a valid measure of oil price uncertainty in subsequent analyses.

Initially, the first-order and second-order autocorrelation tests (Arellano-Bond) were conducted, and the results are presented in the following table.

Table 6. First- and Second-Order Autocorrelation Test

Order	Z-Statistic	Probability
First	-2.76	0.00
Second	-1.41	0.15

Based on the above results, first-order autocorrelation is present, whereas second-order autocorrelation is not. Next, the Sargan test is used to further examine autocorrelation. The results of this test are as follows:

Table 7. Sargan Test for Autocorrelation

Probability	Chi-Square
0.58	12.3

As shown in the table, the probability of the Sargan test statistic is 0.58. Based on this, the null hypothesis stating that the instruments are uncorrelated with the error terms cannot be rejected. Therefore, from these two tests, it can be concluded that the instruments used for estimation are valid.

As previously stated, the research model is expressed as follows:

RE_it = β_0 + β_1 Oilp_it + β_2 Develop_it + β_3 Inno_it + β_4 Hdi_it + ε_it

a. Model Estimation Results for Oil-Importing Countries

The estimation results for oil-importing countries are presented in the following table.

Table 8. Model Estimation Results for Oil-Importing Countries

Model Variables	Coefficient	Z-Statistic	Probability
Oilp	1.27	0.61	0.03
Develop	0.30	0.99	0.00
Inno	0.97	0.54	0.01
Hdi	0.42	1.21	0.00
Cons	1.03	0.21	0.00

The results indicate that oil price volatility is statistically significant at the 95% confidence level, while all other variables are significant at the 99% confidence level.

The findings reveal that a one-unit increase in oil price volatility leads to a 1.27-unit increase in renewable energy consumption. The trade intensity variable has a coefficient of 0.30, meaning that a one-unit increase in trade intensity results in a 0.30-unit increase in renewable energy consumption. The innovation coefficient is 0.97, indicating that a one-unit increase in innovation leads to a 0.97-unit increase in renewable energy consumption. The human capital development variable has a coefficient of 0.42, suggesting that a one-unit increase in this variable results in a 0.42-unit increase in renewable energy consumption.

4. Discussion and Conclusion

The findings of this study demonstrate that oil price volatility, trade intensity, innovation, and human capital development all significantly influence renewable energy consumption in oil-importing countries. The results indicate that a one-unit increase in oil price volatility leads to a 1.27-unit increase in renewable energy consumption. Similarly, trade intensity positively affects renewable energy consumption, with a one-unit increase in trade development resulting in a 0.30-unit increase in renewable energy use. Innovation and human capital development also contribute significantly, with coefficients of 0.97 and 0.42, respectively, implying that economies with higher levels of technological advancement and human capital are more inclined toward renewable energy adoption. These findings underscore the growing significance of structural economic factors in shaping energy transition dynamics in oil-importing nations.

The positive relationship between oil price volatility and renewable energy consumption aligns with the theory that higher oil price uncertainty drives the need for alternative energy sources. Mohsin et al. (2021) demonstrated that renewable energy plays a crucial role in reducing carbon emissions and that transitioning from non-renewable to renewable energy sources is essential for long-term environmental sustainability [41]. The findings of the present study suggest that oil price fluctuations act as a key driver for this transition, as countries seek to mitigate risks associated with fossil fuel dependency. Similarly, Adebayo et al. (2021) found that increased renewable energy consumption reduces environmental degradation in Sweden, emphasizing that governments must focus on public awareness and policy measures to accelerate the adoption of renewable sources [42]. These findings reinforce the idea that energy markets react to oil price volatility by increasing investments in renewable energy infrastructure.

The positive impact of trade intensity on renewable energy consumption is consistent with the argument that global economic integration facilitates technology transfer and innovation, ultimately promoting sustainable energy solutions. Alvarado et al. (2021) emphasized that globalization and human capital are critical for shifting toward a sustainable energy mix in OECD countries [43]. This aligns with the present study's findings, which indicate that trade expansion contributes to renewable energy consumption, likely by providing access to advanced renewable energy technologies and capital investments.

The role of innovation in promoting renewable energy consumption further validates the argument that technological advancements are crucial for reducing dependence on fossil fuels. Mohsin et al. (2021) found that an increase in renewable energy consumption leads to lower carbon emissions, reinforcing the need for innovative solutions in energy production [41]. The present study's results highlight that economies investing in research and development (R&D) for clean energy technologies are more likely to expand their renewable energy portfolios. This finding is supported by Adebayo et al. (2021), who identified technological progress as a determinant of sustainable energy transitions [42]. Similarly, Alvarado et al. (2021) argued that economic development alone is insufficient to drive energy transitions without a strong focus on human capital and innovation [43].

The significant impact of human capital development on renewable energy consumption indicates that educated and skilled labor forces play a key role in facilitating the adoption of renewable energy technologies. The findings of Alvarado et al. (2021) reinforce this idea, as they found that human capital contributes to reducing reliance on fossil fuels by fostering knowledge-driven economic transitions [43]. The present study corroborates this argument by demonstrating that countries with higher levels of human capital development are more likely to integrate renewable energy sources into their energy mix. This relationship suggests that investments in education and workforce training are essential for ensuring a smooth transition toward sustainable energy systems.

The economic implications of these findings are particularly relevant for oil-importing countries, where reliance on fossil fuel markets exposes them to significant price risks. In sum, the results of this study are aligned with previous research, which suggests that economic factors such as oil price volatility, trade integration, innovation, and human capital development play critical roles in shaping renewable energy consumption patterns. The findings contribute to the broader literature by providing empirical evidence from oil-importing countries, offering insights into how market and policy mechanisms influence the transition toward sustainable energy.

This study has several limitations that should be considered when interpreting the results. First, the dataset covers only ten oil-importing countries, which limits the generalizability of the findings to a broader global context. While these countries represent significant players in the global energy market, including additional economies from different regions could provide a more comprehensive understanding of renewable energy adoption patterns. Second, the study relies on aggregate macroeconomic indicators, which may not fully capture country-specific institutional and regulatory factors that influence renewable energy consumption. The heterogeneity of policy frameworks, incentives, and subsidies across countries could introduce unobserved variations that affect the results. Third, the analysis is based on historical data from 2000 to 2022, which may not fully account for recent technological advancements and policy changes that are currently shaping energy transitions. Future research could address these limitations by incorporating more granular data, expanding the sample size, and analyzing the role of specific policy interventions.

Future research should explore the role of policy frameworks in facilitating the transition to renewable energy sources in oil-importing countries. While this study highlights the importance of economic factors such as oil price volatility, trade intensity, innovation, and human capital, further investigation into regulatory measures, carbon pricing, and subsidy structures could provide deeper insights into effective policy strategies. Additionally, future studies could employ dynamic modeling techniques to capture the evolving nature of energy markets, particularly in response to geopolitical shifts and technological breakthroughs. Another promising avenue for research is the examination of sectoral variations in renewable energy adoption, as different industries may exhibit distinct responses to economic and policy drivers. Comparative studies between developed and developing economies could also shed light on the varying institutional capacities that influence the effectiveness of renewable energy policies.

Policymakers in oil-importing countries should focus on reducing dependence on fossil fuels by implementing strategies that enhance renewable energy adoption. This includes investing in research and development for clean energy technologies, providing financial incentives for businesses to transition to renewable sources, and strengthening trade agreements that facilitate technology transfer. Governments should also prioritize human capital development by integrating renewable energy education into academic curricula and vocational training programs, ensuring that the workforce is equipped with the necessary skills for sustainable energy transitions. Additionally, regulatory frameworks should be designed to stabilize energy markets against oil price volatility by promoting energy diversification and establishing long-term incentives for renewable energy investments. Collaboration between public and private sectors is essential to drive innovation and expand renewable energy infrastructure, creating a sustainable and resilient energy system for the future.

Authors' Contributions

Authors equally contributed to this article.

Acknowledgments

Authors thank all participants who participate in this study.

Declaration of Interest

The authors report no conflict of interest.

Funding

According to the authors, this article has no financial support.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

References

[1] M. Murshed, "Does improvement in trade openness facilitate renewable energy transition? Evidence from selected South Asian economies," *South Asia Economic Journal*, vol. 19, no. 2, pp. 151-170, 2018. [Online]. Available: https://doi.org/10.1177/1391561418794691.

[2] M. Murshed, "Electricity conservation opportunities within private university campuses in Bangladesh," *Energy and Environment*, vol. 31, pp. 256-274, 2019. [Online]. Available: https://doi.org/10.1177/0958305X19857209.

[3] M. Murshed, "Are Trade Liberalization policies aligned with renewable energy transition in low and middle income countries? An instrumental variable approach," 2020. [Online]. Available: https://doi.org/10.1016/j.renene.2019.11.106.

[4] P. Villavicencio Calzadilla and R. Mauger, "The UN's new sustainable development agenda and renewable energy: the challenge to reach SDG7 while achieving energy justice," *Journal of Energy and Natural Resources Law*, vol. 36, no. 2, pp. 233-254, 2018. [Online]. Available: https://doi.org/10.1080/02646811.2017.1377951.

[5] S. V. Valentine, "Emerging symbiosis: renewable energy and energy security," *Renewable and Sustainable Energy Reviews*, vol. 15, no. 9, pp. 4572-4578, 2011. [Online]. Available: https://doi.org/10.1016/j.rser.2011.07.095.

[6] J. Zemin, "Reflections on energy issues in China," *Journal of Shanghai Jiaotong University*, vol. 3, p. 2, 2008.

[7] S. Perry, J. Klemes, and I. Bulatov, "Integrating waste and renewable energy to reduce the carbon footprint of locally integrated energy sectors," *Energy*, vol. 33, no. 10, pp. 1489-1497, 2008. [Online]. Available: https://doi.org/10.1016/j.energy.2008.03.008.

[8] A. Albatayneh, "The Significance of Renewable Energy in a Water-Scarce World: A Case Study of Jordan," *Air Soil and Water Research*, vol. 17, 2024, doi: 10.1177/11786221241261827.

[9] Deloitte Insights. "2024 renewable energy industry outlook." https://www2.deloitte.com/us/en/insights/industry/renewable-energy/renewable-energy-industry-outlook.html (accessed.

[10] J. E. Rentschler, "Oil price volatility, economic growth and the hedging role of renewable energy," 2013. [Online]. Available: https://doi.org/10.1596/1813-9450-6603.

[11] Y. C. Shen, G. T. Lin, K. P. Li, and B. J. Yuan, "An assessment of exploiting renewable energy sources with concerns of policy and technology," *Energy Policy*, vol. 38, no. 8, pp. 4604-4616, 2010. [Online]. Available: https://doi.org/10.1016/j.enpol.2010.04.016.

[12] M. O. Oseni, "Improving households' access to electricity and energy consumption pattern in Nigeria: renewable energy alternative," *Renewable and Sustainable Energy Reviews*, vol. 16, no. 6, pp. 3967-3974, 2012. [Online]. Available: https://doi.org/10.1016/j.rser.2012.03.010.

[13] T. Urmee, D. Harries, and A. Schlapfer, "Issues related to rural electrification using renewable energy in developing countries of Asia and Pacific," *Renewable Energy*, vol. 34, no. 2, pp. 354-357, 2009. [Online]. Available: https://doi.org/10.1016/j.renene.2008.05.004.

[14] R. Sen and S. C. Bhattacharyya, "Off-grid electricity generation with renewable energy technologies in India: an application of HOMER," *Renewable Energy*, vol. 62, pp. 388-398, 2014. [Online]. Available: https://doi.org/10.1016/j.renene.2013.07.028.

[15] R. Sari, B. T. Ewing, and U. Soytas, "The relationship between disaggregate energy consumption and industrial production in the United States: an ARDL approach," *Energy Economics*, vol. 30, no. 5, pp. 2302-2313, 2008. [Online]. Available: https://doi.org/10.1016/j.eneco.2007.10.002.

[16] E. Llera, S. Scarpellini, A. Aranda, and I. Zabalza, "Forecasting job creation from renewable energy deployment through a value chain approach," *Renewable and Sustainable Energy Reviews*, vol. 21, pp. 262-271, 2013. [Online]. Available: https://doi.org/10.1016/j.rser.2012.12.053.

[17] F. Ahmad, "The effect of oil prices on employment; evidence from Pakistan," *Business and Economic Research Journal*, vol. 4, no. 1, pp. 1-43, 2013.

[18] T. Akinlo and O. T. Apanisile, "The impact of volatility of oil price on the economic growth in Sub-Saharan Africa," *British Journal of Economics, Management and Trade*, vol. 5, no. 3, pp. 338-349, 2015. [Online]. Available: https://doi.org/10.9734/BJEMT/2015/12921.

[19] N. Apergis and J. E. Payne, "The causal dynamics between renewable energy, real GDP, emissions and oil prices: evidence from OECD countries," *Applied Economics*, vol. 46, no. 36, pp. 4519-4525, 2014. [Online]. Available: https://doi.org/10.1080/00036846.2014.964834.

[20] I. Berk and B. Aydogan, "Crude Oil Price Shocks and Stock Returns; evidence from Turkish Stock Market Under Global Liquidity Conditions," 2012.

[21] M. H. Berument, N. B. Ceylan, and N. Dogan, "The impact of oil price shocks on the economic growth of selected MENA countries," *The Energy Journal*, vol. 31, no. 1, pp. 149-176, 2010. [Online]. Available: https://doi.org/10.5547/ISSN0195-6574-EJ-Vol31-No1-7.

[22] R. Brini, M. Amara, and H. Jemmali, "Renewable energy consumption, international trade, oil price and economic growth inter-linkages: The case of Tunisia," *Renewable and Sustainable Energy Reviews*, vol. 76, pp. 620-627, 2017. [Online]. Available: https://doi.org/10.1016/j.rser.2017.03.067.

[23] J. Cunado, S. Jo, and F. P. de Gracia, "Macroeconomic impacts of oil price shocks in Asian economies," *Energy Policy*, vol. 86, pp. 867-879, 2015. [Online]. Available: https://doi.org/10.1016/j.enpol.2015.05.004.

[24] J. Cunado and F. Perez de Gracia, "Oil prices, economic activity and inflation: Evidence for some Asian countries," *The Quarterly Review of Economics and Finance*, vol. 45, no. 1, pp. 65-83, 2005. [Online]. Available: https://doi.org/10.1016/j.qref.2004.02.003.

[25] P. Deniz, "Oil Prices and Renewable Energy: An Analysis for Oil Dependent Countries," *J. Res. Econ.*, vol. 3, pp. 139-152, 2015. [Online]. Available: https://doi.org/10.35333/JORE.2019.52.

[26] R. Eyden, M. Difeto, R. Gupta, and M. E. Wohar, "Oil price volatility and economic growth: Evidence from advanced economies using more than a century's data," *Applied Energy*,

pp. 612-621, 2019. [Online]. Available: https://doi.org/10.1016/j.apenergy.2018.10.049.

[27] H. Guo and K. L. Klieses, "Oil price volatility and the U.S. Macroeconomic activity," *Federal Reserve Bank of St. Louis Review*, vol. 86, pp. 669-683, 2005.

[28] R. Jiménez-Rodríguez and M. Sánchez, "Oil price shocks and real GDP growth: Empirical evidence for some OECD countries," *Applied Economics*, vol. 37, no. 2, pp. 201-228, 2005. [Online]. Available: https://doi.org/10.1080/0003684042000281561.

[29] A. Kiani, "Impact of high oil prices on Pakistan's economic growth," *International Journal of Business and Social Science*, vol. 2, no. 17, pp. 209-216, 2011.

[30] A. Malik, "Crude oil price, monetary policy and output: the case of Pakistan," *The Pakistan Development Review*, vol. 47, pp. 425-436, 2008.

[31] F. Musa, "The long run effects of oil prices on economic growth: The case of Saudi Arabia," *International Journal of Energy Economics and Policy*, vol. 7, no. 6, pp. 171-192, 2017.

[32] S. Nazir and A. Qayyum, "Impact of Oil Price and Shocks on Economic Growth of Pakistan: Multivariate Analysis," 2014.

[33] P. Sadorsky, "Renewable energy consumption, CO2 emissions and oil prices in the G7 countries," *Energy Economics*, vol. 31, no. 3, pp. 456-462, 2009. [Online]. Available: https://doi.org/10.1016/j.eneco.2008.12.010.

[34] S. Shavalpour and E. Kavyani, "The impact of oil price fluctuations on wind power capacity in developing countries with an emphasis on the role of technical learning and economies of scale," *Journal of Iranian Energy Economics*, vol. 7, no. 26, pp. 25-50, 2018. [Online]. Available: https://doi.org/10.22054/jiee.2018.9098.

[35] M. A. Madani and Z. Ftiti, "Understanding Intraday Oil Price Dynamics During the COVID-19 Pandemic: New Evidence From Oil and Stock Investor Sentiments," *The Energy Journal*, vol. 45, no. 3, pp. 57-86, 2024, doi: 10.5547/01956574.45.3.mmad.

[36] S. Mamipour, S. Yazdani, and E. Sepehri, "Examining the Spillover Effects of Volatile Oil Prices on Iran's Stock Market Using Wavelet-Based Multivariate GARCH Model," *Journal of Economics and Finance*, vol. 46, no. 4, pp. 785-801, 2022, doi: 10.1007/s12197-022-09587-7.

[37] A. Bugshan, S. Alnahdi, H. Ananzeh, and F. Alnori, "Does oil price uncertainty affect earnings management? Evidence from GCC markets," *International Journal of Energy Sector Management*, vol. 16, no. 6, pp. 1240-1258, 2022, doi: 10.1108/IJESM-05-2021-0003.

[38] N. Seifollahi and H. Seifollahi Anar, "Examining the Mechanism of the Impact of Exchange Rate Fluctuations, Oil Prices, and Economic Growth on the Overall Tehran Stock Exchange Index," *Financial Economics*, vol. 15, no. 55, pp. 333-353, 2021. [Online]. Available: https://www.magiran.com/paper/2371909/investigating-the-mechanism-of-fluctuation-exchange-rate-oil-price-and-economic-growth-on-the-tehran-securities-exchange?lang=en.

[39] J. D. Hamilton, "Oil and the macroeconomy since World War II," *Journal of Political Economy*, vol. 91, pp. 228-248, 1983. [Online]. Available: https://doi.org/10.1086/261140.

[40] A. Fossaceca, "Assessing the Determinants of the Human Development Index in Oil-Dependent Nations," *Undergraduate Economic Review*, vol. 16, no. 1, p. 19, 2020.

[41] M. Mohsin, H. W. Kamran, M. A. Nawaz, M. S. Hussain, and A. S. Dahri, "Assessing the impact of transition from nonrenewable to renewable energy consumption on economic growth-environmental nexus from developing Asian economies," *Journal of Environmental Management*, vol. 284, p. 111999, 2021. [Online]. Available: https://doi.org/10.1016/j.jenvman.2021.111999.

[42] T. S. Adebayo, H. Rjoub, G. D. Akinsola, and S. D. Oladipupo, "The asymmetric effects of renewable energy consumption and trade openness on carbon emissions in Sweden: new evidence from quantile-on-quantile regression approach," *Environmental Science and Pollution Research*, pp. 1-12, 2021. [Online]. Available: https://doi.org/10.1007/s11356-021-15706-4.

[43] R. Alvarado *et al.*, "Do economic development and human capital decrease non-renewable energy consumption? Evidence for OECD countries," *Energy*, vol. 215, p. 119147, 2021. [Online]. Available: https://doi.org/10.1016/j.energy.2020.119147.