Innovations in Environmental Economics

www.iee.reapress.com

Innov. Environ. Econ. Vol. 2, No. 1 (2026) 67–80.

Paper Type: Original Article

From Industrial Expansion to Green Transition: Revisiting Climate Change Dynamics in Oil-Producing Countries

Seyed Fakhreddin Fakhrhosseini[1,*], Ricardo Marcão[2,3], Alireza Fekri[4]

[1] Department of Management and Accounting, Karaj Branch, Islamic Azad University, Karaj, Iran; sf.fakhrhosseini@iau.ac.ir.
[2] NECE-UBI, Universidade da Beira Interior, 6201-001 Covilhã, Portugal; ricardo.marcao@islasantarem.pt.
[3] ISLA Santarém - Polytechnic University, 2000-029 Santarém, Portugal; ricardo.marcao@islasantarem.pt.
[4] Department of Financial Management, Karaj Branch, Islamic Azad University, Karaj, Iran; alirezafekri1993@gmail.com.

Citation:

Received: 26 September 2025 *Revised: 16 December 2025* *Accepted: 02 February 2026*	Fakhrhosseini, S. F., Marcão, R., & Fekri, A. (2026). From industrial expansion to green transition: Revisiting climate change dynamics in oil-producing countries. *Innovations in Environmental Economics, 2*(1), 67-80.

Abstract

Oil-producing countries play a critical role in global greenhouse gas emissions due to their structural dependence on fossil fuels. This study examines the dynamic effects of economic growth, industrialization, Foreign Direct Investment (FDI), renewable energy consumption, and the Human Development Index (HDI) on Climate Change (CE) in selected oil-producing economies over the period 2005–2025. Using a Panel Vector Autoregression (Panel VAR) framework, alongside Impulse Response Functions (IRF) and Forecast Error Variance Decomposition (FEVD), the study explores both short-run and long-run dynamic interactions among the variables. The findings reveal that industrialization is the most persistent and influential driver of CE, accounting for more than 6% of environmental fluctuations in the long run. In contrast, renewable energy consumption and human development exhibit weak and statistically insignificant mitigating effects within the dynamic framework. Moreover, the impacts of FDI and economic growth on climate change remain relatively limited over extended forecasting horizons. The results suggest that the carbon-intensive industrial structure of oil-dependent economies continues to dominate environmental outcomes, while the current scale of renewable energy adoption remains insufficient to offset environmental degradation. The study highlights the necessity of green industrial transformation, renewable energy expansion, and sustainability-oriented development policies to achieve long-term environmental sustainability.

Keywords: Climate change, Oil-producing countries, Industrialization, Renewable energy consumption, Human development index, Panel vector autoregression.

1 | Introduction

Energy has long been recognized as the lifeblood of human development and a fundamental driver of economic, social, and industrial progress. Nevertheless, the persistent dependence on fossil fuel resources such as oil, natural gas, and coal has generated unprecedented environmental consequences on a global scale.

Corresponding Author: sf.fakhrhosseini@iau.ac.ir
https://doi.org/10.48313/iee.v2i1.70

The combustion of fossil fuels constitutes the primary source of greenhouse gas emissions, particularly carbon dioxide (CO2), which has substantially intensified global warming and climate change [1], [2]. These environmental challenges threaten natural ecosystems, food security, public health, and long-term global economic sustainability, thereby emphasizing the urgent need to transform existing patterns of energy production and consumption.

Over recent decades, climate change has emerged as one of the most critical global concerns, attracting increasing attention from scholars in the fields of energy economics, environmental studies, and social sciences [3]. Consequently, a growing body of literature has focused on examining the complex interactions among economic globalization, economic growth, human development, and environmental sustainability [4]. Within this framework, the concept of human development has gained substantial importance, as it extends beyond conventional measures of economic growth to incorporate broader dimensions such as education, health, and standards of living. Improving human well-being and achieving sustainable development are inherently linked to environmental protection and ecological preservation.

Economic activities, particularly those heavily reliant on fossil fuel consumption, continue to represent the principal source of environmental degradation and greenhouse gas emissions [5]. In response to these growing threats, the transition toward renewable energy sources, including solar, wind, and biomass energy, has become a central strategy for mitigating climate change and achieving carbon neutrality. This transition not only reduces dependence on fossil fuels and enhances energy security but also stimulates green innovation and sustainable economic growth [6]. However, the impacts of macroeconomic indicators such as economic growth, Foreign Direct Investment (FDI), and industrialization on environmental degradation remain highly debated in the literature [7], [8]. The Environmental Kuznets Curve (EKC) hypothesis, alongside the competing "Pollution Haven" and "Pollution Halo" hypotheses regarding FDI, highlights the complexity of these relationships and their dependence on institutional quality, economic structure, and development levels across countries [9].

Despite the extensive literature in energy economics and environmental sustainability, no clear consensus has yet been reached concerning the causal relationships among macroeconomic indicators, renewable energy consumption, human development, and climate change. While numerous studies report that renewable energy consumption significantly contributes to reducing carbon emissions and improving environmental quality (Idroes et al. [10] ; Fakher et al. [11]), others argue that these effects vary across regions and income groups or may even be statistically insignificant under certain conditions. These inconsistencies underscore the necessity for further empirical investigations, particularly within country-specific and region-specific contexts. In this regard, oil-producing countries represent a particularly important case. Due to their structural dependence on oil revenues and fossil fuel-based economic systems, these countries face unique challenges and opportunities in the transition toward cleaner energy systems and environmental sustainability. On the one hand, the dominance of carbon-intensive industries and energy sectors exacerbates environmental degradation; on the other hand, substantial financial resources generated from oil revenues provide significant potential for investment in renewable energy infrastructure and green technologies.

Accordingly, the present study aims to investigate the effects of key economic indicators, namely industrialization, economic growth, FDI, and TRO, alongside renewable energy consumption and the Human Development Index (HDI), on climate change, proxied by carbon emissions, in selected oil-producing countries. By employing a Panel Vector Autoregression (Panel VAR) framework, this study seeks to provide a comprehensive dynamic analysis of the interactions among these variables and to answer the following fundamental question: How do macroeconomic indicators, renewable energy consumption, and human development influence climate change in oil-producing countries? The findings of this study are expected to contribute to the existing literature by offering new empirical evidence regarding the environmental dynamics of oil-dependent economies and by providing policy implications for achieving sustainable development and green transition strategies in such countries. The remainder of the paper is structured as follows. Section 2 presents the literature review. Section 3 outlines the research methodology and data description. Section 4 reports and discusses the empirical findings, while Section 5 concludes the study and provides policy implications.

2 | Literature Review and Theoretical Background

The intricate and multidimensional relationship among economic development, energy consumption, and environmental degradation, particularly in the context of climate change, has become one of the central themes in environmental economics. This relationship assumes even greater importance in oil-producing countries, whose economic structures are fundamentally dependent on fossil fuel revenues. Understanding the theoretical foundations governing these interactions is therefore essential for designing effective policies aimed at achieving low-carbon and sustainable economic transitions.

2.1 | Economic Indicators and Climate Change

The most widely recognized theoretical framework explaining the relationship between economic growth and environmental degradation is the EKC hypothesis. According to this hypothesis, environmental degradation initially increases during the early stages of economic development due to intensified industrialization, urbanization, and resource exploitation. However, after reaching a certain income threshold, further economic growth contributes to environmental improvement through technological advancement, stricter environmental regulations, and structural transformation toward service-oriented economies, thereby producing an inverted U-shaped relationship between income and environmental degradation [4]. Nevertheless, the validity of the EKC hypothesis remains controversial, particularly in resource-dependent economies such as oil-producing countries, where fossil fuel dependence may hinder environmental improvements despite economic expansion.

In addition to economic growth, FDI constitutes another critical determinant of environmental quality. The environmental implications of FDI are generally explained through two competing hypotheses. The first is the Pollution Haven Hypothesis, which argues that multinational corporations relocate pollution-intensive industries from developed countries with strict environmental regulations to developing countries characterized by weaker regulatory frameworks, thereby increasing environmental degradation in host economies. In contrast, the Pollution Halo Hypothesis suggests that FDI facilitates the transfer of cleaner technologies, advanced managerial practices, and environmentally efficient production methods, ultimately improving environmental quality in recipient countries. The overall impact of FDI, therefore, depends largely on factors such as institutional quality, technological capacity, and environmental governance within the host economy [9]. Industrialization also represents a major driver of climate change, particularly during the early stages of development. Rapid industrial expansion typically increases energy demand and fossil fuel consumption, leading to higher greenhouse gas emissions and environmental deterioration. This issue is especially relevant in oil-producing countries, where industrial sectors are often highly energy-intensive and carbon-dependent.

2.2 | Renewable Energy Consumption and Climate Change

The transition from fossil fuels toward renewable energy sources is widely regarded as one of the most effective strategies for combating climate change. Renewable energy technologies, including solar, wind, hydroelectric, and biomass energy, produce substantially lower carbon emissions compared to conventional fossil fuel-based energy systems. Consequently, increasing the share of renewable energy within national energy portfolios can significantly reduce CO_2 emissions and enhance environmental sustainability. Previous studies consistently emphasize the complementary role of renewable energy consumption and green technological innovation in mitigating environmental degradation and achieving carbon neutrality goals [1], [2]. However, for oil-producing countries, the transition toward renewable energy presents a dual challenge. On the one hand, it requires substantial investments in new infrastructure and technological capabilities; on the other hand, it directly challenges the traditional economic model based on fossil fuel extraction and export revenues.

2.3 | Human Development and Climate Change

The HDI, which encompasses education, health, and living standards, provides a broader perspective on development beyond conventional income-based indicators such as GDP. The relationship between human development and climate change is theoretically ambiguous. Higher levels of human development may increase environmental awareness, strengthen public demand for environmental quality, and enhance societies' capacity to invest in cleaner technologies and sustainable production systems. Educated and healthier populations are generally more likely to support environmentally responsible policies and sustainable lifestyles. Conversely, improvements in human development are often accompanied by higher levels of consumption, urbanization, and energy demand, all of which may contribute to increased greenhouse gas emissions. Therefore, the net effect of HDI on climate change largely depends on country-specific socioeconomic structures, consumption patterns, institutional quality, and environmental policies.

2.4 | Empirical Literature Review

Obobisa [12], in a study examining the role of eco-innovation, clean energy, and trade openness in carbon neutrality and sustainable development for OECD countries. Their findings demonstrated that eco-innovation, clean energy utilization, and human capital have a negative impact on CO2 emissions. Trade openness and economic growth have a positive impact on CO2 emissions except that trade impact is insignificant. Khan and Ozturk [2] investigated the relationship between financial development and carbon emissions in 88 developing countries over the period 2000–2014 using system Generalized Method of Moments. The results revealed an inverted U-shaped relationship. Additionally, The results support the pollution inhibiting role of financial development. The environmental consequences of financial development have been widely explored in the existing literature, with evidence provided by Fakher [13], Fakher [14], and Fakher et al. [15]. This strand of evidence is further reinforced by the findings of Tithi [16] and Zani et al. [17]. Their results found that they improved environmental quality. Li et al. [18] analyzed the the impact of geopolitical risks (GPR) on the global transition to renewable energy (RE) and its implications for energy security (ES), with a focus on the differential effects across advanced, developing, and least-developed economies. The results show that geopolitical risks accelerate RE adoption in advanced economies, while hindering progress in developing economies due to institutional and financial constraints. In least-developed economies, energy dependence exacerbates the negative impacts of geopolitical risks. Adebayo et al. [4], employing a nonlinear panel ARDL (NARDL) model for BRICS countries, examined the asymmetric effects of renewable energy consumption and technological innovation on carbon emissions. Their findings indicated that renewable energy consumption significantly reduces CO2 emissions, while technological innovation improves environmental quality in the long run. The study also confirmed the validity of the EKC hypothesis for BRICS economies. Huo et al. [1] explored the role of green innovation, renewable energy consumption, and globalization in mitigating carbon emissions across G7 countries using panel quantile regression techniques. Their results showed that green innovation constitutes the most influential factor in reducing emissions, particularly in highly polluted economies, while globalization contributes positively through the diffusion of cleaner technologies. Pata et al. [9] examined the dynamic relationship among FDI, renewable energy consumption, economic growth, and CO2 emissions in the Association of Southeast Asian Nations countries. Their findings revealed that foreign direct investment increase CO2 emissions. Real income and trade openness reduce environmental degradation. Since the long-run income elasticity is lower than the short-run, the EKC hypothesis is valid. Additionally, they found that renewable energy reduces carbon emissions only in the short term and has no effect on environmental quality in the long term.

Several domestic studies have also investigated environmental sustainability and renewable energy dynamics. Izadi and Gomshadzehi [19], using the Panel ARDL approach for Shanghai Cooperation Organization member states, concluded that income inequality significantly increases carbon emissions, whereas renewable energy consumption and education contribute to environmental improvement. Sotoudeh Nia Korrani et al. [20], employing the Structural VAR (SVAR) model for Iran, reported that renewable energy consumption and technological innovation negatively affect climate change, while industrialization and urbanization intensify environmental degradation. Despite the growing body of literature, several research gaps remain evident. First, most previous studies have primarily focused on developed or upper-middle-income economies, while limited attention has been devoted to oil-producing countries characterized by fossil fuel dependency and unique institutional structures. Second, relatively few studies have simultaneously incorporated macroeconomic indicators, renewable energy consumption, and the HDI within a unified dynamic framework. Third, empirical evidence concerning oil-producing economies remains fragmented and inconclusive, particularly regarding the dynamic interactions among industrialization, renewable energy transition, and climate change. Accordingly, the present study seeks to address these gaps by providing a comprehensive dynamic analysis of the impacts of economic indicators, renewable energy consumption, and human development on climate change in selected oil-producing countries using the Panel VAR framework.

3 | Methodology

The present study is applied in terms of an objective and quantitative nature based on panel data analysis. The statistical population consists of oil-producing countries located in the Middle East and North Africa (MENA) region. Using a systematic elimination approach based on data availability, the final sample includes 13 countries: the United Arab Emirates, Bahrain, Algeria, Iraq, Iran, Jordan, Kuwait, Morocco, Egypt, Oman, Saudi Arabia, Syria, and Tunisia. The study covers the period from 2005 to 2025. The required data were collected through documentary and library-based methods from internationally recognized databases. Specifically, data for climate change indicators, renewable energy consumption, industrialization, FDI, TRO, and Gross Domestic Product (GDP) were obtained from the World Bank database, while HDI data were extracted from the United Nations Development Programme (UNDP). All variables were compiled in the form of a balanced panel dataset for the selected countries over the study period.

In our model, climate change (CE) is considered the dependent variable in this study, while renewable energy consumption (RE), HDI, industrialization (IND), foreign direct investment (FDI), TRO, and real GDP are incorporated as explanatory variables. For a better explanation, Eq *(1)* provides the study's research model, covering the association between these variables.

$$\begin{aligned} CE_{it} = \alpha_i &+ \sum_{j=1}^{p} \beta_{1j} CE_{i,t-j} + \sum_{j=1}^{p} \beta_{2j} RE_{i,t-j} + \sum_{j=1}^{p} \beta_{3j} HDI_{i,t-j} + \sum_{j=1}^{p} \beta_{4j} IND_{i,t-j} \\ &+ \sum_{j=1}^{p} \beta_{5j} FDI_{i,t-j} + \sum_{j=1}^{p} \beta_{6j} TRO_{i,t-j} + \sum_{j=1}^{p} \beta_{7j} GDP_{i,t-j} + \varepsilon_{it}. \end{aligned} \quad (1)$$

To investigate the long-run relationship among the variables, the Kao [21] panel cointegration test was employed. Subsequently, a Panel VAR model with one lag was estimated using the Generalized Method of Moments (GMM) approach. The Panel VAR framework was selected because of its ability to capture the dynamic interrelationships among variables while treating all variables as potentially endogenous within the system.

Furthermore, several post-estimation analyses were conducted to examine the dynamic behavior of the model. These include Impulse Response Functions (IRF), based on Cholesky decomposition with 95% confidence intervals, and Forecast Error Variance Decomposition (FEVD) over forecasting horizons from one to ten periods. The IRF analysis allows for evaluating the response of climate change to shocks originating from the explanatory variables over time, whereas the FEVD analysis identifies the relative contribution of each variable in explaining fluctuations in climate change across different time horizons.

To assess the statistical adequacy and robustness of the estimated model, diagnostic indicators including the coefficient of determination (R^2), adjusted coefficient of determination (Adjusted R^2), F-statistic, and Durbin–Watson statistic were also examined. These measures provide evidence regarding the explanatory power, goodness-of-fit, and absence of serial correlation in the residuals of the estimated model.

4 | Results and Discussion

4.1 | Descriptive Statistics

Table 1 presents the descriptive statistics of the variables employed in the study for the selected oil-producing countries. The mean and median values of most variables, including TRO, FDI, human development (HDI), renewable energy consumption (RE), climate change indicator (CE), and GDP, are relatively close to each other, indicating a fairly symmetric distribution of the data and the absence of severe outlier bias.

Among the variables, industrialization (IND) exhibits the highest standard deviation (1.30), reflecting substantial heterogeneity among the selected oil-producing countries in terms of industrial development. In contrast, renewable energy consumption (RE) and GDP demonstrate relatively lower standard deviations, suggesting comparatively stable distributions across the sample countries. Moreover, the range between the maximum and minimum values is particularly large for FDI and industrialization, indicating considerable structural differences among the selected economies regarding foreign investment attraction and industrial capacity.

Table 1. Descriptive statistics of the variables.

Variable	Symbol	Mean	Median	Maximum	Minimum	Std. Dev.
Climate change	CE	2.15	2.23	3.01	0.28	0.46
Renewable energy	RE	3.47	3.46	4.04	2.78	0.27
Human development	HDI	3.21	3.23	4.14	2.45	0.41
Industrialization	IND	4.91	4.53	8.66	3.46	1.30
Foreign direct investment	FDI	19.58	14.29	23.77	13.80	1.53
Trade openness	TRO	10.35	10.40	11.30	9.24	0.45
Real GDP	GDP	3.91	3.67	5.56	3.28	0.45

Source: Authors' calculations.

4.2 | Panel Unit Root Test

To determine the stationarity properties of the variables and select the appropriate estimation approach, the Fisher-type panel unit root test based on the Augmented Dickey–Fuller (ADF) procedure was employed. The null hypothesis of the test assumes the presence of a unit root (non-stationarity). The results reported in *Table 2* indicate that the variables FDI, GDP, and IND are stationary at levels, as their probability values are below the 5% significance level. In contrast, CE, RE, HDI, and TRO are found to be non-stationary at the level form. Consequently, the model contains a mixture of I(0) and I(1) variables. This outcome justifies the application of econometric techniques capable of accommodating variables integrated at different orders within a unified framework.

Table 2. Results of the Panel Unit Root Test

Variable	Fisher Statistic	Probability	Result
CE	46.23	0.60	Non-stationary
RE	34.80	0.11	Non-stationary
HDI	25.47	0.49	Non-stationary
IND	20.72	0.75	Stationary
FDI	61.90	0.000	Stationary
TRO	19.20	0.74	Non-stationary
GDP	66.00	0.000	Stationary

Source: Authors' calculations.

4.3 | Kao Panel Cointegration Test

To examine the existence of a long-run equilibrium relationship among the variables, the Kao [21] panel cointegration test was applied. The null hypothesis assumes the absence of cointegration among the variables. As presented in *Table 3*, the estimated t-statistic equals -3.82 with a probability value of 0.0001, which is statistically significant at the 5% level. Therefore, the null hypothesis is rejected, confirming the existence of a long-run equilibrium relationship among climate change, renewable energy consumption, human development, industrialization, FDI, TRO, and economic growth in the selected oil-producing countries. This finding supports the suitability of estimating the Panel VAR model.

Table 3. Kao panel cointegration test results.

t-statistic	Prob	Result
-3.82	0.0001	Cointegration Exists

Source: Authors' calculations

4.4 | Estimation Results of the Panel VAR Model

The estimation results of the Panel VAR model with one lag are presented in *Table 4*. Overall, the model demonstrates satisfactory explanatory power, as indicated by the adjusted coefficient of determination (Adjusted $R^2 = 0.68$), implying that approximately 68% of the variations in climate change are explained by the included explanatory variables. Furthermore, the Durbin–Watson statistic (2.19) confirms the absence of serial correlation in the residuals, indicating an appropriate model specification. The lagged value of climate change [CE(-1)] exhibits a positive and statistically significant coefficient (0.19), highlighting the persistent and cumulative nature of environmental degradation. This finding suggests that nearly 19% of the previous period's climate change effects are transmitted into the current period, emphasizing the long-term persistence of environmental shocks. Renewable energy consumption [RE(-1)] has a negative and statistically significant coefficient (-0.22), indicating that increased utilization of renewable energy sources contributes to mitigating climate change. Specifically, a one-unit increase in renewable energy consumption reduces climate change intensity by approximately 0.22 units. This finding underscores the importance of transitioning from fossil fuel dependency toward cleaner energy sources in oil-producing countries. Similarly, the Human Development Index [HDI(-1)] exerts a negative and significant effect on climate change (-0.11), implying that improvements in education, health, and living standards may enhance environmental awareness and facilitate the adoption of cleaner technologies and environmentally responsible behaviors. In contrast, industrialization [IND(-1)] displays a positive but statistically insignificant coefficient, suggesting that its direct short-run effect may be partially absorbed through other channels such as economic growth and structural transformations within the selected economies. Foreign direct investment [FDI(-1)] shows a negative and statistically significant impact on climate change (-0.21), supporting the Pollution Halo Hypothesis. This result suggests that foreign investments may facilitate the transfer of environmentally friendly technologies and advanced managerial practices, thereby contributing to environmental improvement in host countries. Trade openness [TRO(-1)] records the strongest mitigating effect on climate change, with a significant coefficient of -1.24. This finding indicates that integration into global markets, access to cleaner technologies, and increased competitiveness in environmentally sustainable production may substantially improve environmental quality. Conversely, real GDP [GDP(-1)] exhibits a positive coefficient (0.26), supporting the scale effect hypothesis, whereby economic expansion in oil-producing countries continues to be associated with increased environmental degradation and carbon emissions. *Fig. 1* presents a graphical summary of the main empirical findings of the study.

Table 4. Panel VAR estimation results.

Variable	Coefficient	t-statistic	Probability
CE(-1)	0.19	4.93	0.0000
RE(-1)	-0.22	-2.99	0.0023
HDI(-1)	-0.11	-4.72	0.0000
IND(-1)	0.21	0.80	0.4110
FDI(-1)	-0.21	-3.80	0.0002
TRO(-1)	-1.24	-4.36	0.0000
GDP(-1)	0.26	2.07	0.0430
Diagnostic Tests			
R-squared	0.70	F	29.61
Adjusted R-squared	0.68	Durbin-Watson	2.19

Source: Authors' calculations.

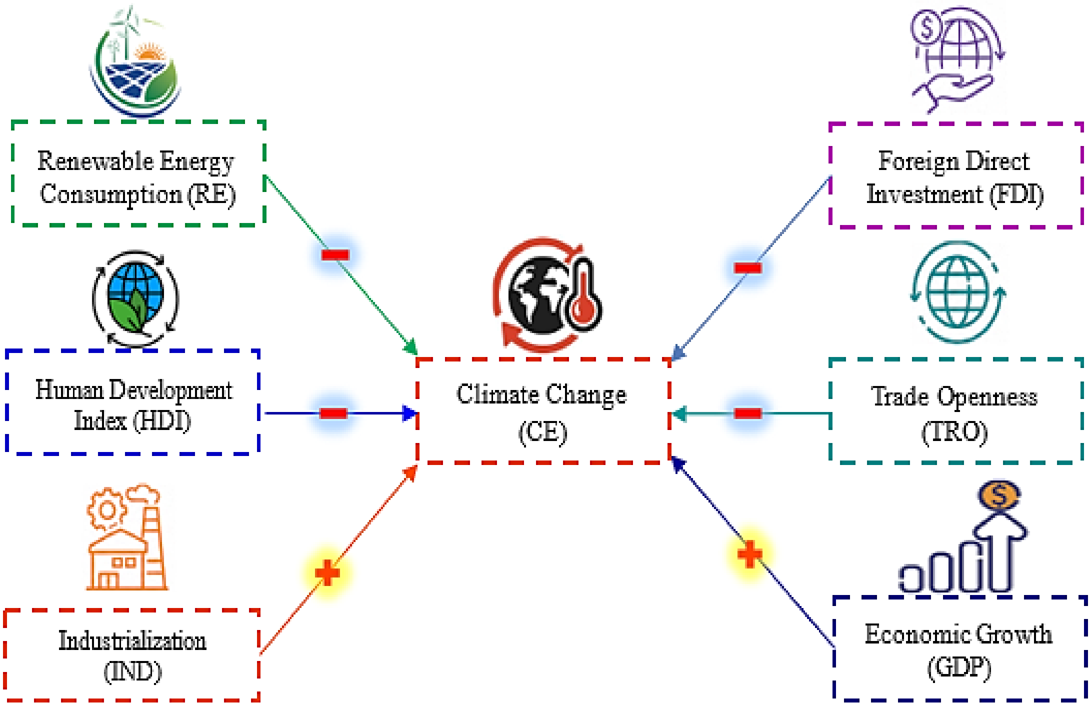

Fig. 1. Graphical summary of the main empirical findings.

4.5 | Impulse Response Function (IRF) Analysis

The presented figures illustrate the results of the Impulse Response Function (IRF) analysis based on Cholesky decomposition. These graphs depict the response of climate change (CE) to a one-standard-deviation shock in each variable of the model over a ten-period forecasting horizon. The solid blue line represents the point estimate of the response, while the red dashed lines indicate the 95% confidence intervals. If the confidence interval includes the zero line, the response is considered statistically insignificant. A positive shock to climate change exerts a positive and statistically significant effect on itself. The impact reaches its peak during the second period and then gradually declines over time; however, it remains positive and statistically significant until the end of the forecasting horizon (the tenth period). This finding reflects the strong persistence and long-lasting nature of climate-related shocks.

A shock originating from renewable energy consumption does not generate any statistically significant response in climate change. The response function remains very close to zero throughout the entire forecasting horizon, and the confidence intervals continuously intersect the horizontal axis, indicating statistical insignificance. Similarly, a shock to the HDI does not produce a statistically significant impact on climate change. The confidence intervals include the zero line across all periods, implying the absence of a meaningful dynamic response. A positive shock to industrialization leads to a positive and statistically significant response in climate change. This effect becomes statistically significant from the second period onward and remains persistent in the long run. The finding suggests that the expansion of industrial activities contributes substantially to the intensification of climate change in oil-producing countries. The impulse generated by FDI does not produce a statistically significant effect on climate change during the examined period. The confidence intervals consistently encompass the zero line, indicating weak dynamic transmission effects. Likewise, a shock to real GDP fails to create a statistically significant response in climate change, as the confidence intervals include the zero line throughout the forecasting horizon.

Overall, the impulse response analysis demonstrates that among the examined variables, only industrialization (IND) exerts a positive and statistically significant impact on the intensification of climate change (CE). Moreover, shocks to climate change itself exhibit considerable persistence over time. In contrast, renewable energy consumption, human development, FDI, and economic growth do not display statistically significant dynamic effects on climate change within the estimated Panel VAR framework.

A comparison between the regression coefficient estimates reported in *Table 4* and the impulse response results illustrated in *Fig. 2* reveals several important insights. While the regression coefficients capture the short-run and direct effects of explanatory variables on climate change within a one-period lag structure, the IRF reflects the dynamic propagation of shocks throughout the entire system over time. The statistical insignificance of some variables in the IRF analysis, despite their significance in the regression estimates, may be attributed to two main factors. First, the complex feedback mechanisms and interdependencies embedded within the Panel VAR system may cause the initial effects of shocks to dissipate over time through systemic interactions and stochastic disturbances. Second, the relatively conservative nature of the Monte Carlo confidence intervals used in IRF simulations makes them more sensitive to minor fluctuations compared to standard regression coefficients. Nevertheless, the statistical significance of industrialization in the IRF analysis confirms that this variable possesses a deeper structural and more persistent influence on climate change relative to the other explanatory variables included in the model. The summary of the empirical findings is illustrated in *Fig. 2*.

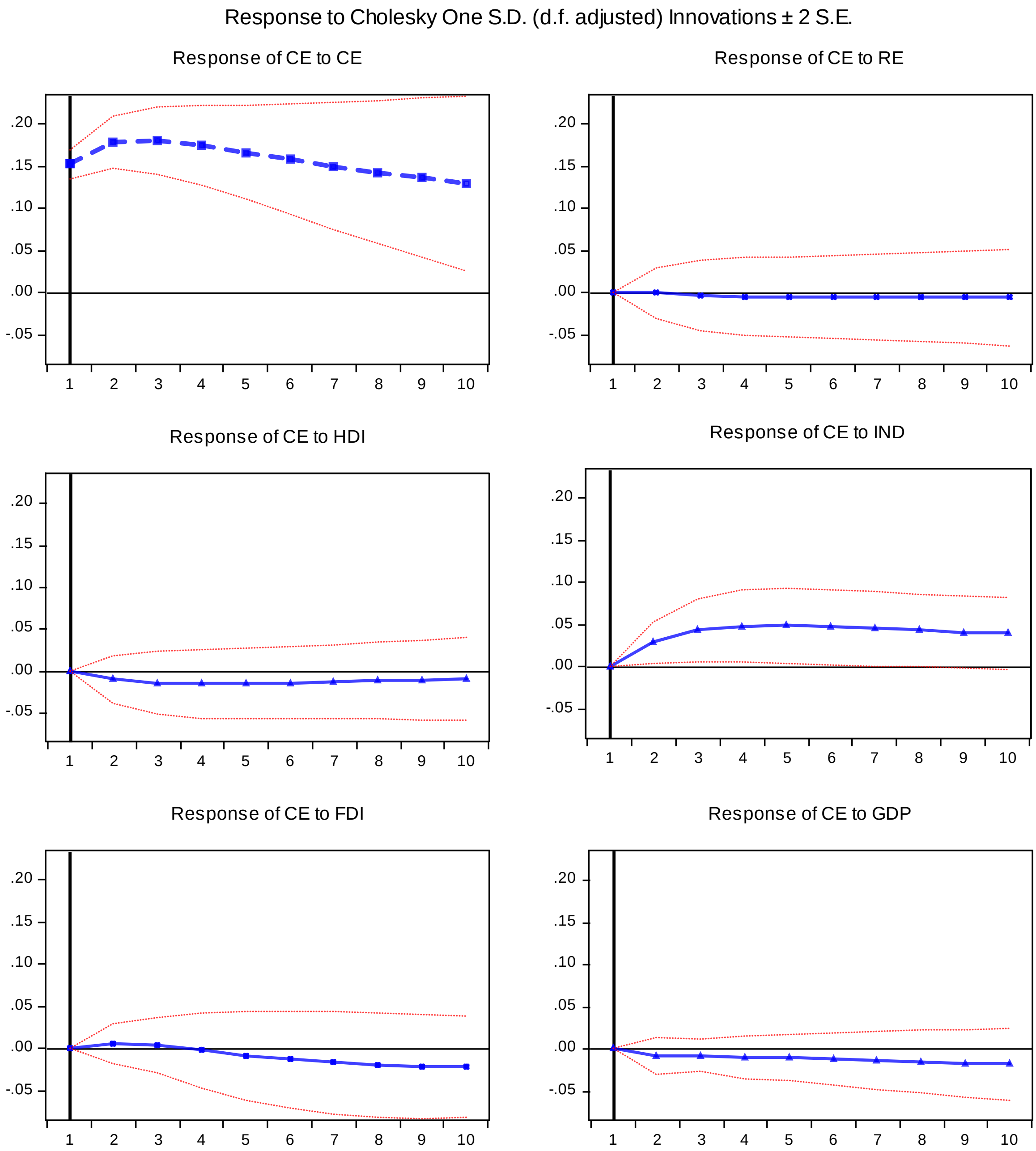

Fig. 2. Dynamic response of climate change to shocks in the explanatory variables.

4.6 | Forecast Error Variance Decomposition (FEVD)

Variance decomposition analysis illustrates the extent to which structural shocks to each variable in the model contribute to forecasting errors in climate change (CE) across different time horizons. The results presented in *Table 5* can be interpreted as follows: In the first period, all fluctuations in climate change (CE) are entirely explained by shocks to the variable itself (100%), while the contributions of all other variables remain zero. This outcome is expected and reflects the lag structure inherent in the VAR framework. As the forecasting horizon increases from period 2 to period 10, the explanatory power of climate change's own shocks gradually declines from 100% to approximately 91.85% in the tenth period. Simultaneously, the contributions of the other explanatory variables progressively increase over time.

Among the explanatory variables, industrialization (IND) exhibits the largest non-own explanatory contribution. Its share rises steadily and reaches approximately 6.30% of the forecast error variance of climate change by the tenth period. This finding suggests that industrialization becomes the most influential external determinant of climate change in oil-producing countries over the long run. The remaining variables contribute relatively modest shares to the forecast error variance of climate change. Specifically, by the tenth period, human development (HDI) explains approximately 0.58%, renewable energy consumption (RE) accounts for about 0.06%, FDI contributes nearly 0.65%, and GDP explains around 0.56% of the forecast error variance in CE. An important observation is that the explanatory contributions of FDI and GDP exhibit a gradual upward trend at higher forecasting horizons, indicating that the effects of these variables on climate change materialize progressively over time.

Overall, the findings indicate that climate change dynamics in oil-producing countries are predominantly driven by the internal dynamics of the climate change variable itself. Nevertheless, industrialization (IND) emerges as the most important external shock influencing climate change in the long run. In contrast, the relatively weak explanatory power of renewable energy consumption and human development may reflect the limited penetration of clean energy technologies and the insufficient integration of sustainability considerations within the development structures of oil-dependent economies.

Table 5. FEVD of Climate change (CE).

Period	S.E.	CE	RE	HDI	IND	FDI	GDP
1	0.153018	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.237792	98.08968	0.000333	0.185644	1.517583	0.069115	0.137648
3	0.302200	96.37944	0.007062	0.360627	3.039666	0.061011	0.152191
4	0.352951	95.12527	0.021999	0.467944	4.143739	0.047721	0.193331
5	0.393994	94.24020	0.033961	0.531221	4.886344	0.078774	0.229496
6	0.427973	93.57203	0.042159	0.565225	5.385283	0.157550	0.277755
7	0.456693	93.04198	0.047744	0.581328	5.727270	0.268178	0.333505
8	0.481408	92.59648	0.052345	0.585898	5.970780	0.394344	0.400156
9	0.502987	92.20697	0.056946	0.583213	6.152505	0.523553	0.476810
10	0.522050	91.85387	0.062218	0.575912	6.295407	0.648494	0.564104

Source: Authors' calculations.

5 | Conclusion and Policy Implications

The present study investigated the impacts of key economic indicators, including economic growth, industrialization, TRO, and FDI, alongside renewable energy consumption and human development, on climate change in selected oil-producing countries over the period 2005–2025. By employing the Panel VAR framework, the study provided a dynamic analysis of the interactions among the variables. The major findings can be summarized as follows.

First, the results demonstrate that industrialization constitutes the most influential and persistent driver of climate change in oil-producing countries. Both the impulse response analysis and the FEVD confirm that industrialization exerts a positive and long-lasting impact on environmental degradation. In particular, the FEVD results indicate that industrialization explains approximately 6.30% of climate change fluctuations in the long run, which exceeds the explanatory power of all other external variables included in the model. This finding highlights the dominant role of carbon-intensive industrial structures in intensifying environmental pressures within oil-dependent economies. Second, contrary to theoretical expectations, renewable energy consumption and human development exhibit relatively weak and statistically insignificant long-run dynamic effects on climate change. Although renewable energy consumption and HDI display negative coefficients in the regression analysis, their explanatory contributions in the dynamic framework remain minimal. This outcome may reflect the still-limited share of renewable energy within the energy portfolios of oil-producing countries, as well as the insufficient integration of environmental awareness and sustainability considerations into human development processes. Third, while FDI and economic growth display certain effects on environmental quality in the short-run estimation results, their long-run explanatory contributions remain relatively limited. The FEVD findings reveal that both FDI and GDP account for less than 1% of climate change fluctuations over longer forecasting horizons. These findings suggest that environmental degradation in oil-producing economies is driven more strongly by domestic industrial structures than by external capital inflows or aggregate economic expansion alone.

Overall, the findings indicate that climate change dynamics in oil-producing countries are primarily shaped by the internal persistence of environmental shocks and the structural dominance of industrialization. Meanwhile, renewable energy transition and human development policies have not yet achieved sufficient effectiveness to offset the environmental consequences of fossil fuel dependency. Based on these findings, several policy implications can be proposed. Given the substantial contribution of industrialization to climate change, policymakers in oil-producing countries should prioritize the transition toward green industrialization strategies. Such a transition requires replacing outdated and carbon-intensive technologies with cleaner and energy-efficient production systems. Since renewable energy currently plays only a marginal role in mitigating climate change, governments should provide stronger fiscal incentives, subsidies, and financial support for renewable energy projects, particularly in the solar and wind sectors, to increase the share of clean energy within national energy portfolios. Policymakers should incorporate environmental education and sustainability awareness into human development programs to ensure that improvements in education and living standards contribute to environmentally responsible behaviors rather than unsustainable consumption patterns. Governments should adopt stricter environmental regulations regarding foreign investment projects, ensuring that incoming FDI contributes to the transfer of green technologies and sustainable production methods rather than reinforcing pollution-intensive industrial activities. In conclusion, achieving environmental sustainability in oil-producing countries requires a comprehensive transformation of industrial structures, energy systems, and development policies. Without substantial progress toward renewable energy transition and green economic restructuring, the environmental challenges associated with fossil fuel dependency are likely to persist in the long run.

Authors' Contributions

S. F. F.: Writing-original draft, Methodology, Data Curation, Conceptualization, Software, Formal Analysis, and Visualization, and Validation. R. M.: Validation, Writing-Review & Editing, Software, and Formal Analysis. A. F.: Validation, Writing-Review & Editing, and Formal Analysis. The authors have read and agreed to the published version of the manuscript.

Data Availability

The data is available on request from the corresponding author.

Funding

No external funding was received for this research.

Conflict of Interest

There are no competing interests to declare.

Consent for Publication

The authors have given consent for the publication of this manuscript.

Ethics Approval and Consent to Participate

The authors confirm that this research did not involve human participants or animal subjects.

References

[1] Trivedi, K., & Koley, S. (2023). Mathematical modeling of oscillating water column wave energy converter devices placed over an undulated seabed in a two-layer fluid system. *Renewable energy*, *216*, 119092. https://doi.org/10.1016/j.renene.2023.119092

[2] Khan, M., & Ozturk, I. (2021). Examining the direct and indirect effects of financial development on CO2 emissions for 88 developing countries. *Journal of environmental management*, *293*, 112812. https://doi.org/10.1016/j.jenvman.2021.112812

[3] Fakher, H. A. (2020). Analytical insights on the relationship between economic growth and environmental degradation in framework of EKC hypothesis and various environmental indicators. *Innovation management and operational strategies*, *1*(3), 252–268. (**In Persian**). https://doi.org/10.22105/imos.2021.272348.1032

[4] Mighri, Z., & AlSaggaf, M. I. (2023). Asymmetric impacts of renewable energy consumption and economic complexity on economic growth in Saudi Arabia: Evidence from the NARDL model. *Environmental science and pollution research*, *30*(3), 7446–7473. https://doi.org/10.1007/s11356-022-22718-1

[5] Hosan, M. Z., Hossain, M. S., Esquivias, M. A., Mazumder, S., Rahman, Z., & others. (2026). Economic Globalization, Financial Development, Renewable Energy, and the Environmental Kuznets Curve: Evidence from 26 Major Global Economies. *Nature-based solutions*, 100354. https://doi.org/10.1016/j.nbsj.2026.100354

[6] Shobande, O. A., Ogbeifun, L., & Tiwari, A. K. (2023). Re-evaluating the impacts of green innovations and renewable energy on carbon neutrality: Does social inclusiveness really matters? *Journal of environmental management*, *336*, 117670. https://doi.org/10.1016/j.jenvman.2023.117670

[7] Fakher, H. A., Abedi, Z., Ahmadian, M., & Shaygani, B. (2018). Comparative examine the impact of financial development (based on money market and capital market) in the intensity of economic growth effects on the environmental performance. *Environmental researches*, *9*(17), 133–146. (**In Persian**). https://www.iraneiap.ir/article_79310_b837783b87485d1e63ce5b76ef59206d.pdf

[8] Fakher, H. A. (2021). The role of environmental sustainability, foreign direct investment and trade openness in economic growth: with emphasis on the causal linkage. *Big data and computing visions*, *1*(2), 57–70. https://doi.org/10.22105/bdcv.2021.142227

[9] Pata, U. K., Dam, M. M., & Kaya, F. (2023). How effective are renewable energy, tourism, trade openness, and foreign direct investment on CO2 emissions? An EKC analysis for ASEAN countries. *Environmental science and pollution research*, *30*(6), 14821–14837. https://doi.org/10.1007/s11356-022-23160-z

[10] Idroes, G. M., Fakher, H. A., Hilal, I. S., & Wiranatakusuma, D. B. (2026). N-Shaped or Inverted N-Shaped EKC? The Role of Renewable and Non-Renewable Energy in Environmental Sustainability. *Ekonomikalia journal of economics*, *4*(1), 58–87. https://heca-analitika.com/eje/article/download/400/268

[11] Fakher, H. A., Panahi, M., Emami, K., Peykarjou, K., Zeraatkish, S. Y., & others. (2021). New insight into development of environmental-economic model based on a composite environmental quality index: an application of principal components analysis. *Journal of decisions and operations research*, *6*(2), 183–209. (**In Persian**). https://dor.isc.ac/dor/20.1001.1.25384988.2021.5.3.6.4

[12] Obobisa, E. S. (2024). An econometric study of eco-innovation, clean energy, and trade openness toward carbon neutrality and sustainable development in OECD countries. *Sustainable development*, *32*(4), 3075–3099. https://doi.org/10.1002/sd.2829

[13] Fakher, H. A., & others. (2023). The impact of gross domestic product, financial development, energy consumption on environmental quality: With emphasis on six environmental indicators. *Journal of natural environment*, *76*(2), 345–363. (**In Persian**). https://jne.ut.ac.ir/article_90898_9c281e9b2d6c9c75ec4a4884a2c0a527.pdf

[14] Fakher, H. A. (2022). Threshold impact of financial development on the composite environmental quality index with emphasis on the role of research and development: using multi-criteria decision makin and principal component analysis. *Journal of decisions and operations research*, *6*(Special Issue), 1–25. (**In Persian**). https://doi.org/10.22105/dmor.2021.272043.1321

[15] Fakher, H. A., Panahi, M., Emami, K., Peykarjou, K., & Zeraatkish, S. Y. (2021). New insight into examining the role of financial development in economic growth effect on a composite environmental quality index. *Environmental science and pollution research*, *28*(43), 61096–61114. https://doi.org/10.1007/s11356-021-15047-2

[16] Tithi, S. I. (2025). Pathways to carbon neutrality in the united states: evaluating private ai investment, financial development, and macroeconomic forces. *International journal of business and economic studies*, *7*(4), 231–242. https://doi.org/10.54821/uiecd.1831647

[17] Zani, S., Tithi, S. I., Farukh, M. O., Rafi, A. H., Ahsan, M. T., Hasan, M. M., & Islam, M. S. (2025). Do finance and digitalization foster environmental sustainability? Evidence from US carbon emissions. *Kristu jayanti journal of management sciences (KJMS)*, 45–66. https://www.kristujayantijournal.com/index.php/ijcm/article/download/2575/1952

[18] Li, Y., Hanif, M. W., Wen, M., Khoso, A. K., & Khoso, W. M. (2026). Geopolitical risks and the global renewable energy transition: Implications for energy security and economic resilience. *Energy reports*, *15*, 108875. https://doi.org/10.1016/j.egyr.2025.12.012

[19] Izadi, H., & Gumshadzei, A. (2025). Comparing and examining the effects of income inequality on air pollution; case study: Shanghai Cooperation Organization member countries. *Environmental science studies*, *10*(3), 10690–10704. https://www.jess.ir/article_231696_8555cd620c2ffdfcbffb7e628e567052.pdf

[20] SotodhaNaya Karani, S., Sadeghi, M., & Arabi, H. (2024). Investigating the impact of technological innovation in renewable energies on climate change in Iran (with a look at paragraph 7 of the general policies for reforming consumption patterns). *Quarterly scientific research journal of economic strategy*, *13*(51), 603–626. (**In Persian**). https://doi.org/10.22034/es.2025.495342.1825

[21] Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of econometrics*, *90*(1), 1–44. https://doi.org/10.1016/S0304-4076(98)00023-2