Management Strategies and Engineering Sciences 2025; 7(5):1-11

Analyzing the Impact of Renewable Energy Investment on Reducing Healthcare Costs in Low-, Middle-, and High-Income Countries in the Middle East

Ashkan Khoz[1], Afshin Baghfalaki[2*] Kambiz Peykarjou[1] Abbas Memarnejad [1]

[1] Department of Economics, SR.C., Islamic Azad University, Tehran, Iran
[2] Department of Economics, Ker.C., Islamic Azad University, Tehran, Iran

*** Corresponding author email address**: Afshin.Baghfalaki@iau.ac.ir

Received: 2025-01-18 **Reviewed:** 2025-06-21 **Revised:** 2025-06-28 **Accepted:** 2025-07-03 **Published:** 2025-09-01

Abstract

This study examines the impact of investment in renewable energy on reducing healthcare costs in Middle Eastern countries, taking into account their income levels (low, middle, and high). Air pollution, as one of the main causes of cardiovascular, respiratory, and chronic diseases, imposes heavy annual burdens on healthcare systems. In this research, data related to investments in renewable energy, healthcare expenditures, and economic indicators were collected from reputable international sources and analyzed using multivariate regression models. The results indicated that increased investment in renewable energy significantly contributes to reducing healthcare costs. This effect is more evident in high-income countries due to greater access to financial resources and more advanced infrastructure. Additionally, the Middle East's substantial potential for harnessing solar and wind energy presents a significant opportunity to reduce dependence on fossil fuels and improve public health. However, low-income countries, due to financial and structural constraints, require international support and appropriate policy interventions. This study emphasizes the importance of adopting incentive policies for the development of renewable energy and fostering regional cooperation in the Middle East. It also provides recommendations for strengthening infrastructure and addressing economic disparities. The findings of this study can assist policymakers in designing sustainable strategies to reduce healthcare costs and enhance quality of life.

Keywords: *foreign direct investment, renewable energy, healthcare costs, Middle Eastern countries.*

How to cite this article:

Khoz, A., Baghfalaki, A., Peykarjou, K., & Memarnejad, A. (2025). Analyzing the Impact of Renewable Energy Investment on Reducing Healthcare Costs in Low-, Middle-, and High-Income Countries in the Middle East. Management Strategies and Engineering Sciences, 7(5), 1-11.

1. Introduction

The growing urgency of environmental sustainability has prompted governments, investors, and policymakers to explore renewable energy as a strategic lever for both ecological and economic transformation. In particular, the Middle East, with its vast untapped renewable resources, is increasingly being recognized not only for its historical dependence on fossil fuels but also for its emerging potential in the global transition toward clean energy [1, 2]. However, achieving this transition is complex and multifaceted, requiring substantial foreign direct investment (FDI), enabling policy environments, and coordinated efforts across sectors to mitigate the rising environmental challenges, especially pollution. Carbon dioxide (CO_2) emissions, a primary contributor to climate change, are heavily influenced by energy consumption patterns, economic activities, and demographic factors [1]. Consequently, understanding how renewable energy investments and FDI influence CO_2 emissions in the Middle Eastern context is essential for shaping effective and sustainable development strategies.

Recent studies have underscored the critical role that renewable energy investments play in mitigating environmental degradation while fostering economic growth. In China, for example, investment in renewable energy has been found to significantly stimulate renewable energy development, particularly when thresholds of economic maturity and policy readiness are considered [3]. This observation is mirrored in findings from G7 countries, where environmental regulations and financial development have jointly facilitated the renewable energy transition, suggesting a strong interplay between governance mechanisms and capital allocation [4]. Similarly, ASEAN nations have recognized the imperative of attracting greater investment into renewable infrastructure to advance their clean energy agendas and reduce CO_2 emissions [5]. These cases highlight the potential of investment-driven policy interventions as a cornerstone of environmental sustainability.

In parallel, FDI serves as a crucial channel for transferring advanced technologies, managerial expertise, and financial capital into developing economies. Empirical research has demonstrated that FDI can act as a double-edged sword: while it can promote economic growth and green technology diffusion, it may also exacerbate environmental degradation if directed toward pollution-intensive sectors [6]. This dichotomy is especially pertinent to the Belt and Road Initiative (BRI) countries, where the environmental impact of FDI varies substantially depending on the host country's regulatory framework and energy composition [2]. In the case of China, the intricate linkages among energy consumption, pollutant emissions, and FDI inflows reveal that strategic investment alignment is key to decoupling growth from environmental harm [7]. These findings indicate that the effectiveness of FDI in contributing to environmental objectives is contingent on targeted policy designs and institutional capacity.

The dynamics of FDI and renewable energy investment are further influenced by the evolving risk landscape associated with transitioning to clean energy. In India, for instance, strategic risks—ranging from policy uncertainty to grid integration challenges—continue to deter renewable energy ambitions despite strong investor interest [8]. Similar concerns have been raised in Iran, where renewable energy investment is constrained by market inefficiencies and geopolitical uncertainties, requiring innovative financial instruments such as real options to manage risk exposure [1]. These barriers to renewable energy development are compounded in regions like the Middle East, where fossil fuel subsidies, limited institutional support, and volatile political environments often undermine investment confidence. Hence, addressing these structural and systemic impediments is essential for catalyzing a sustainable energy transition in the region.

Population dynamics and economic development also play significant roles in shaping environmental outcomes. Research conducted across OECD countries has shown that energy innovation investment correlates strongly with increased renewable energy deployment, emphasizing the need for knowledge spillovers and demographic adaptability in energy policy frameworks [9]. Meanwhile, the interaction between demographic growth and energy demand has been linked to rising CO_2 emissions, particularly in emerging markets where infrastructure and urban planning lag behind population expansion [10]. This is particularly relevant to the Middle East, where rapid population growth intensifies the demand for energy and increases the strain on environmental systems. Understanding the mediating effects of income levels and energy efficiency is therefore vital to crafting inclusive and sustainable development policies.

In ASEAN countries, an Environmental Kuznets Curve (EKC) framework has been applied to assess how trade openness, tourism, renewable energy, and FDI jointly influence CO_2 emissions. The findings suggest a nonlinear relationship, indicating that environmental degradation may initially rise with economic growth and investment before eventually declining as economies mature and adopt cleaner technologies [11]. A similar trend was observed in E-7 nations, where education emerged as a critical variable in moderating the effects of green investment and FDI on environmental performance [10]. These insights imply that socioeconomic variables such as education, institutional quality, and public awareness can significantly alter the environmental impact of investment strategies.

Policy instruments also play a decisive role in steering investment flows toward environmentally beneficial outcomes. A recent study of the power supply chain illustrates how stringent environmental policies can significantly influence renewable energy investment decisions by altering risk perceptions and return expectations [12]. In developing countries, supporting the green development transition through targeted subsidies, policy consistency, and technical assistance has been identified as a key enabler of long-term environmental and economic resilience [13]. In addition, the incorporation of behavioral dimensions, such as the influence of tax incentives on investors' decision-making processes, further enriches our understanding of how policy design affects renewable energy uptake [14].

The case of European countries provides further empirical support for the interconnectedness of renewable energy, FDI, and environmental outcomes. Using a panel ARDL approach, researchers found robust evidence of long-run relationships among these variables, with heterogeneity across country groups reflecting variations in policy effectiveness and economic structures [15]. Earlier studies had already highlighted similar patterns among Kyoto Protocol Annex countries, showing that while both renewable energy and FDI can reduce CO_2 emissions, their effectiveness is conditional on country-specific factors such as industrial composition and environmental enforcement [16].

Given these diverse global experiences, the Middle East presents a unique context for examining the nexus among FDI, renewable energy investment, and environmental degradation. With abundant solar and wind resources, the region has immense potential to diversify its energy mix and reduce its reliance on fossil fuels. Yet, institutional weaknesses, policy fragmentation, and external shocks continue to hinder progress. This study aims to fill the existing gap in empirical literature by analyzing how FDI and renewable energy investment impact pollution—measured through CO_2 emissions—across selected Middle Eastern countries, while accounting for population growth, health expenditures, and economic development.

2. Methodology

The present study is descriptive-analytical in nature and utilizes secondary data to analyze the relationships between variables. This research employs econometric models and cross-sectional data analysis to examine the impact of investment in renewable energy on healthcare costs. Additionally, to identify differences among countries with varying income levels, the countries were categorized into three income groups: low, middle, and high.

The data used in this research include the following information:

1. **Data on investment in renewable energy**: These data were collected from reputable international sources such as the International Energy Agency (IEA) and the World Bank.
2. **Data on healthcare costs**: Information related to healthcare expenditures resulting from air pollution-related diseases was extracted from the World Health Organization (WHO) and national reports of the countries under study.
3. **Economic and environmental indicators**: Data on gross domestic product (GDP), greenhouse gas emissions, and air quality index were collected from international databases such as the World Environmental Database (WED).

Initially, the collected data are described to provide an overview of the state of investment in renewable energy and healthcare costs in Middle Eastern countries. This analysis includes the mean, standard deviation, and data distribution for key variables.

To investigate the relationship between investment in renewable energy and the reduction of healthcare costs, a multivariate regression model was employed. The proposed model is defined as follows:

$$HC_i = \beta_0 + \beta_1 RI_i + \beta_2 GDP_i + \beta_3 EI_i + \varepsilon_i$$

Where:

- HC_i: Healthcare costs in country *i*
- RI_i: Investment in renewable energy in country *i*
- GDP_i: Gross domestic product of country *i*
- EI_i: Greenhouse gas emission index in country *i*
- ε_i: Model error term

The results of the regression model are compared and analyzed separately for the three income groups (low, middle, and high) to determine the existing differences in the impact of investment on healthcare costs.

To enhance the validity of the findings, the following methods were employed:

- **Data validation**: The data used were extracted from credible and international databases.
- **Sensitivity analysis**: To assess the robustness of the results, alternative models and various control variables were examined.

3. Findings and Results

The symbols of the variables used in this study are as follows:

Table 1. Variables Used in the Model

Variable	Symbol
Environmental Pollution Index	CO_2
Foreign Direct Investment	FDI
Energy Consumption and Efficiency	E

Population Density	PG
Per Capita Income	GDP
Healthcare Costs	HC

This section empirically investigates the effects of foreign direct investment, renewable energy, and healthcare costs on environmental degradation in Middle Eastern countries. For this purpose, the following model is employed. The regression model is specified as:

$CO_{2it} = \alpha_i + \beta_1 FDI_{it} + \beta_2 E_{it} + \beta_3 PG_{it} + \beta_4 GDP_{it} + \beta_5 HC_{it} + \mu_{it}$

Considering the review of available statistics and data for application and use of the findings in the country, statistical data from the period 2013 to 2023 were utilized for 10 selected Middle Eastern countries (Egypt, Iran, Iraq, Kuwait, Jordan, Oman, Lebanon, Saudi Arabia, Syria, and Turkey). Given the research method involving panel data, it was essential to select a number of different countries to allow for comprehensive conclusions about the factors affecting environmental quality. Thus, considering the shared characteristics of Middle Eastern countries, particularly their dependence on fossil fuel resources, these regions were selected for study. More precisely, the aforementioned countries represent the core areas under examination.

Descriptive statistics include a set of methods used for collecting, summarizing, classifying, and describing numerical facts. Essentially, this type of analysis describes the research data and provides a general pattern or outline of the data for more efficient and effective utilization.

Table 2. Descriptive Statistics of Research Variables

Variable	Mean	Minimum	Maximum	Standard Deviation
CO_2	32.2153	0.4	85.85	50.3535
FDI	6.5709	-1.02	7.60	10.3410
E	16.1763	0	87.6	25.6755
PG	1.8373	-6.8521	11.7940	2.7504
GDP	16.4766	2.05	47.72	13.2303
HC	1.4315	7.49	9.82	2.5215

The table above presents the descriptive statistics of the research variables. The most important central tendency measure is the mean, which represents the equilibrium point and the center of the distribution, serving as a suitable index for data centrality. Another descriptive parameter is the standard deviation, which indicates the dispersion of the data. Additionally, the minimum and maximum parameters in the table show the range of data variation. The standard deviation refers to the average squared deviation of each data point from the mean and serves as a key indicator of dispersion.

The results of the unit root test are reported in the table below. Prior to estimating the model, it is necessary to examine the stationarity of its variables. A variable is considered stationary when its mean, variance, and covariance remain constant over time. Generally, if the time origin of a variable changes but its mean, variance, and covariance do not, then the variable is stationary; otherwise, it is non-stationary. The hypotheses related to variable stationarity are as follows:

H_0 = The variable is non-stationary

H_1 = The variable is stationary

The stationarity of the variables is assessed under three conditions: at level, after first differencing, and after second differencing. Variables for which the test yields a probability value below 5% lead to the rejection of the null hypothesis, indicating that the variable is stationary. The unit root test is conducted sequentially for each variable in the model. Given the relatively long time span of this study, the non-stationarity of variables may cause estimation challenges.

Assessing the stationarity of variables before model estimation is of critical importance. For this purpose, several panel data unit root tests have been developed, which are generally categorized into two generations: first-generation and second-generation tests. First-generation tests assume cross-sectional independence in the error term and proceed with the stationarity assessment under this assumption. As noted by Pesaran (2004), this assumption is only valid for panels with a large number of cross-sections. However, when the number of cross-sections is small and the time span is long, the likelihood of cross-sectional dependence in the error term increases. In such cases, first-generation unit root tests lose their efficiency, and second-generation unit root tests must be employed instead.

As shown in the table below, based on the Levin, Lin & Chu (LLC) test, all variables are stationary at level I(0). Therefore, the model can be estimated without concern for spurious regression.

Table 3. Unit Root Test for the Research Variables (Levin, Lin & Chu Test – LLC)

Variable	Test Statistic	p-value	Result
CO_2	-4.99	0.000	Stationary
FDI	0.10	0.000	Stationary
E	-2.94	0.001	Stationary
PG	-9.17	0.000	Stationary
GDP	-27.80	0.000	Stationary
HC	-6.35	0.000	Stationary

It is observed that according to the Levin, Lin & Chu test, all variables are stationary, and thus there is no need to perform cointegration testing. However, to verify the results, a cointegration test is still conducted.

Before estimating the model, it is essential to conduct pre-tests relevant to each econometric model. Therefore, the next step is to test for cointegration among the variables used in this study.

The economic concept of cointegration implies that two or more time series variables are theoretically related such that they form a long-term equilibrium relationship. Although these time series may contain stochastic trends (i.e., be non-stationary), they move together over time in such a way that the difference between them is stable (stationary).

Testing for cointegration in panel data is of great importance. If the variables in the model are not stationary, model estimation may result in a spurious regression. To avoid this, cointegration tests are performed prior to model estimation to ensure the presence of a long-term relationship, which then justifies model estimation.

The concept of cointegration suggests a long-term equilibrium relationship toward which the economic system gradually converges. If the significance level is greater than 5%, the null hypothesis is accepted; otherwise, the alternative hypothesis—indicating the presence of cointegration—is accepted. At this stage, the Pedroni cointegration test is used, which evaluates the long-term integration of variables.

Table 4. Pedroni Cointegration Test Results

Test	Test Statistic	p-value
Panel ADF-Statistic	-5.734	0.015

Based on the ADF statistic and its corresponding p-value, the null hypothesis indicating the absence of cointegration is rejected. Therefore, it can be concluded that the dependent and independent variables share a long-term relationship.

In statistics, the Variance Inflation Factor (VIF) evaluates the severity of multicollinearity in ordinary least squares regression analysis. It introduces an index indicating how much the variance of estimated regression coefficients is increased due to multicollinearity. The results showed that the VIF values for all variables are below the generally accepted threshold of 10.

Table 5. Multicollinearity Assessment Among Variables

Variable	VIF	1/VIF
FDI	1.13	0.72
E	1.14	0.72
PG	1.02	0.89
GDP	1.10	0.90
HC	1.06	0.94

In this study, Spearman's rank correlation was used to assess the correlation among the variables. The results, as shown in the table above, indicate that there is no strong significant correlation among the explanatory variables.

Table 6. Spearman Correlation Matrix Among Study Variables

Variable	FDI	E	PG	HC	GDP
FDI	1.000				
E	0.775	1.000			
PG	-0.282	-0.334	1.000		
HC	-0.022	0.060	-0.015	1.000	
GDP	-0.358	0.012	-0.047	0.122	1.000

The Hausman test is used to determine the appropriate model in panel data analysis. It is based on whether or not there is a correlation between the regression error term and the independent variables. If such a correlation exists, the fixed effects model is appropriate; otherwise, the random effects model is preferred. The hypotheses are formulated as:

H_0 = No correlation between the independent variables and the error term (random effects are appropriate)

H_1 = Correlation exists between the independent variables and the error term (fixed effects are appropriate)

Table 7. Fixed Effects Estimation Results

Variable	Coefficient	Standard Error	p-value
FDI	2.2806	6.0508	0.051
E	6.0399	8.9507	0.012
PG	23.2123	6.1139	0.243
GDP	6.0399	2.2428	0.995
HC	4.3411	19.0311	0.035
C	15.0229	2.2644	0.014

DW = 0.64; F-statistic (Prob) = 0.010; R^2 = 0.83

According to the fixed effects results, all variables in the study—except economic growth (GDP) and population density (PG)—have a positive and significant effect on the dependent variable (carbon dioxide emissions). For example, a one-unit increase in foreign direct investment (FDI) results in a 2.2806 unit increase in CO_2 emissions. After estimating fixed effects, random effects are also evaluated but do not require interpretation for this study.

Table 8. Random Effects Estimation Results

Variable	Coefficient	Standard Error	p-value
FDI	0.3521448	7.04	0.000
E	1.161238	3.15	0.002
PG	0.0268602	0.80	0.425
GDP	0.1682602	1.21	0.227
HC	0.0040011	0.02	0.998
C	—	—	—

DW = 1.85; F-statistic (Prob) = 0.000; R^2 = 0.42

Following both fixed and random effects estimations, the F-Limer test was performed to choose between the fixed effects method and the pooled ordinary least squares (OLS) approach. The results are presented below:

Table 9. F-Limer Test

Test	F-Statistic	p-value
F-Limer	338.80	0.000

The results confirm the preference for the fixed effects method over pooled OLS, as the p-value is less than 0.05. This validates the use of panel data over pooled data. Finally, the Hausman test is conducted.

Table 10. Hausman Test Results

Test Type	Statistic	Significance Level	Conclusion
Hausman	349.21	0.000	Reject H_0 (Random Effects Inappropriate), Accept Fixed Effects

Based on the above results, the Hausman statistic falls within the critical region. Since the p-value is less than 0.05, the null hypothesis (appropriateness of random effects) is rejected, and the fixed effects model is accepted as the superior model.

According to the table below, there is a negative and significant relationship between foreign direct investment (FDI) and pollution emissions. The negative marginal effect of the FDI coefficient on carbon dioxide emissions indicates that if FDI is accompanied by increased pollution and declining environmental quality, it will hinder the path toward sustainable development in these economies. As shown by the results, population growth has a positive and significant effect on carbon dioxide emissions and pollution in the selected Middle Eastern countries. Specifically, with a one-unit increase in population, carbon dioxide emissions increase by 209.9 units.

Table 11. Regression Model

Variable	Coefficient	Standard Error	t-Statistic	p-value
CO_2(-1)	0.853045	0.09375	90.99	0.000
E	-22.68581	172.8311	-0.13	0.0959
FDI	-3.7797	72.8311	-3.76	0.000
GDP	214.49	455.26	0.471	0.638
HC	2.1911	2.2411	0.9068	0.367
PG	209.9	101.06	2.07	0.040

The Sargan test is used to detect whether the error terms in a regression model are uncorrelated with the instrumental variables in econometric studies. If such correlation exists, the model estimators will not be efficient, meaning they do not have minimum variance, rendering the regression analysis and statistical inference unreliable. To validate the Sargan test, the test statistic with (k−q) degrees of freedom should be computed at a 95% confidence level. If the computed statistic is less than the critical chi-square value from standard tables, the null hypothesis is accepted, indicating the model is valid. Similarly, if the p-value is greater than 0.05, the model is considered valid. As shown in the table below, the estimated model is accurate and valid.

Table 12. Sargan Test Results

Test	Test Statistic	p-value
Sargan	28.31	0.077

Given that the use of first-differencing introduces autocorrelation in the error terms of order one, the Arellano-Bond estimator requires testing the order of autocorrelation in the residuals. The Arellano-Bond method produces consistent estimators only when the residuals do not exhibit second-order autocorrelation. The results of testing for first- and second-order autocorrelation are reported below.

Table 13. First- and Second-Order Autocorrelation Test Results (Arellano-Bond)

Description	Z-Statistic	p-value
First Order	-3.0145	0.0026
Second Order	1.118	0.2636

The Z-statistic for the second lag is 1.118, and since the null hypothesis of no second-order autocorrelation in the residuals cannot be rejected, the results confirm that the use of panel data is appropriate.

Based on the data analysis results, each of the study's hypotheses is evaluated as follows:

The first hypothesis states that there is a significant relationship between *foreign direct investment and pollution emissions in Middle Eastern countries*.

The second hypothesis suggests a significant relationship between *energy consumption and pollution emissions in Middle Eastern countries*.

The third hypothesis pertains to the *impact of relative population density on pollution emissions and the relationship between them in Middle Eastern countries*.

The subsequent hypothesis concerns the *positive impact of gross domestic product on pollution emissions in Middle Eastern countries*, and based on the results of the model estimation, the findings support the positive effect of GDP on pollution emissions.

4. Discussion and Conclusion

The findings of this study provide significant insight into the environmental implications of foreign direct investment (FDI) and renewable energy development across selected Middle Eastern countries over the period from 2013 to 2023. The regression results demonstrate a statistically significant and negative relationship between FDI and carbon dioxide (CO_2) emissions. This implies that increased foreign investment—when aligned with sustainable practices—can contribute to environmental improvement in the region. Furthermore, population growth was found to exert a statistically significant and positive impact on CO_2 emissions, underscoring the environmental pressures arising from demographic expansion. While the influence of energy consumption and gross domestic product (GDP) on emissions was positive, it lacked statistical significance in the final model, suggesting that their effects may be mediated by other contextual or structural factors. Health expenditure showed no significant association with emissions, potentially indicating that healthcare investment alone may not directly reduce pollution without corresponding environmental interventions.

The observed negative association between FDI and CO_2 emissions supports the argument that environmentally responsible investment inflows can help reduce environmental degradation in host countries. This aligns with the findings from China, where empirical evidence indicates that FDI, when properly managed and directed toward green sectors, can reduce pollutant emissions while promoting sustainable economic growth [7]. Similar results were reported in OECD countries, where FDI flows into energy innovation were found to positively impact renewable energy adoption and indirectly reduce carbon emissions [9]. Moreover, studies conducted in the ASEAN region have reinforced the importance of structuring FDI frameworks in ways that support renewable energy infrastructure, thereby achieving a dual objective of energy diversification and pollution mitigation [5]. The results of this study further affirm the role of FDI as a policy tool for environmental management, particularly when regulatory environments are conducive to sustainability goals.

Additionally, the positive and statistically significant effect of population growth on CO_2 emissions is consistent with previous literature linking demographic expansion to heightened environmental stress. As urbanization intensifies and energy demand rises, the environmental footprint of growing populations becomes increasingly visible, especially in regions with insufficient infrastructure and limited access to clean technologies [10]. In this context, the Middle East presents a compelling case where population pressure intersects with limited renewable energy penetration, thereby exacerbating pollution levels. This finding is in line with similar studies conducted in Belt and Road Initiative (BRI) countries, where population dynamics significantly influenced environmental degradation unless offset by targeted policy interventions [2]. It suggests that population growth, in the absence of scalable clean energy solutions, may act as a structural driver of pollution in the region.

Although the coefficient for renewable energy consumption was negative—as theoretically expected—its lack of statistical significance in the current model may reflect challenges associated with implementation and scalability. This finding echoes concerns raised in prior research on India's renewable energy sector, where strategic investment risks, infrastructure limitations, and policy inconsistencies have undermined the effectiveness of renewable energy in reducing emissions [8]. Similarly, in Iran, where renewable energy development has been analyzed through a real options framework, market inefficiencies and financing gaps continue to hinder project implementation despite theoretical potential [1]. These challenges are further compounded by institutional constraints and geopolitical uncertainties, which are particularly pronounced in the Middle Eastern context. Thus, the non-significant effect of renewable energy in this study may indicate the presence of structural bottlenecks that limit its environmental effectiveness, rather than a failure of the technology itself.

The absence of a statistically significant relationship between GDP and CO_2 emissions, while somewhat surprising, reflects the complex and potentially non-linear nature of this association. The Environmental Kuznets Curve (EKC) hypothesis posits that pollution initially rises with economic growth before declining as income levels increase and cleaner technologies are adopted. This inverted-U relationship has been confirmed in ASEAN countries, where economic development eventually led to reduced emissions after a certain income threshold was crossed [11]. Similarly, in G7 countries, financial development and strong environmental regulations facilitated a shift toward renewable energy investment, mitigating the growth-pollution trade-off [4]. In the context of the Middle East, however, many countries remain at different stages of economic maturity and may not have yet reached the turning point at which growth contributes to environmental improvement. This could explain the lack of statistical significance in the GDP-emissions relationship in the current analysis.

Health expenditure was also found to be statistically insignificant in its association with CO_2 emissions. While healthcare investment is critical for improving public well-being, its impact on environmental quality is likely indirect and mediated by broader socio-environmental policies. For instance, studies examining policy-driven renewable energy decisions have shown that the health benefits of reduced pollution are most effectively realized when investment strategies integrate environmental and public health objectives [12]. In this study, the disconnection between health spending and emission levels may reflect a policy gap where environmental externalities are not systematically internalized into healthcare and energy budgeting. The finding suggests the need for a more integrated policy framework that links environmental quality improvements to long-term public health investments.

In terms of methodological contributions, this study offers empirical support for the hypothesis that FDI—when properly directed—can be an effective instrument for environmental improvement in emerging economies. This aligns with results from panel ARDL analyses conducted in European and Annex I countries, which demonstrated long-run equilibrium relationships between FDI, renewable energy, and CO_2 emissions [15, 16]. The robustness of these findings across different geopolitical contexts highlights the universality of the investment-emission nexus, while also emphasizing the importance of local conditions such as governance quality, financial markets, and regulatory enforcement in shaping outcomes. In developing countries, support mechanisms such as targeted subsidies and tax incentives have been identified as crucial for stimulating investor confidence and achieving environmental goals [13, 14].

The study also contributes to the theoretical literature by reinforcing the importance of institutional readiness and investor incentives in determining the success of renewable energy transitions. For example, research in China has shown that renewable energy investment effectiveness is sensitive to policy thresholds, indicating that blanket investment strategies may yield uneven results across regions [3]. In the E-7 countries, education was identified as a critical enabler that enhanced the effectiveness of both green investments and FDI in reducing emissions [10]. These findings emphasize the need for tailored investment frameworks that consider country-specific variables such as labor skills, policy coherence, and infrastructure readiness. In the Middle East, addressing these gaps will be essential to fully unlock the environmental potential of foreign investment and clean energy deployment.

Despite its contributions, this study is not without limitations. First, the analysis is constrained by the availability and quality of secondary data, which may vary in accuracy across countries and years. Second, the study uses CO_2 emissions as the sole indicator of environmental degradation, potentially overlooking other forms of pollution such as particulate matter or water contamination. Third, while the regression model includes key control variables such as GDP, population growth, and health expenditures, it may not fully capture the broader institutional and political factors that mediate investment effectiveness. Additionally, the panel data methodology, while robust, assumes homogeneity in effects across countries, which may not reflect the nuanced realities of diverse Middle Eastern economies.

Future research should expand the scope of environmental indicators to include a more holistic assessment of pollution and ecosystem degradation. Incorporating variables such as air quality indices, deforestation rates, and water scarcity metrics would provide a more comprehensive picture of environmental impact. Additionally, future studies could explore the moderating effects of institutional quality, corruption indices, and political stability on the relationship between FDI and environmental outcomes. Comparative analyses between

Middle Eastern countries and other fossil fuel-dependent regions such as North Africa or Central Asia would also offer valuable insights. Finally, qualitative case studies exploring the lived experiences of renewable energy developers, policymakers, and community stakeholders could complement the quantitative findings presented here.

To translate these findings into actionable policy, governments in the Middle East should prioritize the creation of regulatory environments that attract green FDI and de-risk renewable energy investment. Streamlining permitting processes, providing fiscal incentives, and enhancing institutional transparency can help build investor confidence. Public-private partnerships should be leveraged to expand renewable infrastructure and ensure technology transfer. Furthermore, aligning energy investment strategies with demographic trends and urban planning will be essential to manage the environmental pressures arising from population growth. Finally, integrating environmental considerations into national health and economic planning can foster more sustainable and resilient development pathways across the region.

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] S. M. R. Aghaei Marzabali, A. Seyed Mohammad Reza, and Abdollah, "Analysis of Renewable Energy Investment in Iran with a Natural Options Approach," *Iranian Journal of Economic Studies (IJES),* 2023.

[2] A. Khan, J. Hussain, S. Bano, and Y. Chenggang, "The repercussions of foreign direct investment, renewable energy and health expenditure on environmental decay? An econometric analysis of B&RI countries," *Journal of Environmental Planning and Management,* vol. 63, no. 11, pp. 1965-1986, 2020, doi: 10.1080/09640568.2019.1692796.

[3] G. Xu, M. Yang, S. Li, M. Jiang, and H. Rehman, "Evaluating the effect of renewable energy investment on renewable energy development in China with panel threshold model," *Energy Policy,* vol. 187, p. 114029, 2024, doi: 10.1016/j.enpol.2024.114029.

[4] W. Liu, Y. Shen, and A. Razzaq, "How renewable energy investment, environmental regulations, and financial development derive renewable energy transition: Evidence from G7 countries," *Renewable Energy,* vol. 206, pp. 1188-1197, 2023, doi: 10.1016/j.renene.2023.02.017.

[5] R. Vakulchuk, I. Overland, and B. Suryadi, "ASEAN's energy transition: How to attract more investment in renewable energy," *Energy, Ecology and Environment,* vol. 8, no. 1, pp. 1-16, 2023, doi: 10.1007/s40974-022-00261-6.

[6] F. Seker, H. M. Ertugrul, and M. Cetin, "The impact of foreign direct investment on environmental quality: a bounds testing and causality analysis for Turkey," *Renewable and Sustainable Energy Reviews,* vol. 52, pp. 347-356, 2015, doi: 10.1016/j.rser.2015.07.118.

[7] E. N. Udemba, C. Magazzino, and F. V. Bekun, "Modeling the nexus between pollutant emission, energy consumption, foreign direct investment, and economic growth: new insights from China," *Environmental Science and Pollution Research,* vol. 27, no. 15, pp. 17831-17842, 2020, doi: 10.1007/s11356-020-08180-x.

[8] H. H. Gandhi, B. Hoex, and B. J. Hallam, "Strategic investment risks threatening India's renewable energy ambition," *Energy Strategy Reviews,* vol. 43, p. 100921, 2022, doi: 10.1016/j.esr.2022.100921.

[9] E. E. O. Opoku, A. O. Acheampong, K. E. Dogah, and I. Koomson, "Energy innovation investment and renewable energy in OECD countries," *Energy Strategy Reviews,* vol. 54, p. 101462, 2024, doi: 10.1016/j.esr.2024.101462.

[10] P. Xu, J. Zhang, and U. Mehmood, "How do green Investments, foreign direct investment, and renewable energy impact CO2 emissions? Measuring the role of education in E-7 nations," *Sustainability,* vol. 15, no. 19, p. 14052, 2023, doi: 10.3390/su151914052.

[11] U. K. Pata, M. M. Dam, and F. Kaya, "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,* vol. 30, no. 6, pp. 14821-14837, 2023, doi: 10.1007/s11356-022-23160-z.

[12] C. Y. Ji, Z. K. Tan, B. J. Chen, D. C. Zhou, and W. Y. Qian, "The impact of environmental policies on renewable energy investment decisions in the power supply chain," *Energy Policy,* vol. 186, p. 113987, 2024, doi: 10.1016/j.enpol.2024.113987.

[13] F. Li, J. Zhang, and X. Li, "Research on supporting developing countries to achieve green development transition: Based on the perspective of renewable energy and foreign direct investment," *Journal of Cleaner Production,* vol. 372, p. 133726, 2022, doi: 10.1016/j.jclepro.2022.133726.

[14] Y. A. Daiyabu, N. A. A. Manaf, and H. Mohamad Hsbollah, "Extending the theory of planned behaviour with application to renewable energy investment: the moderating effect of tax incentives," *International Journal of Energy Sector Management,* vol. 17, no. 2, pp. 333-351, 2023, doi: 10.1108/IJESM-11-2021-0011.

[15] M. Mert, G. Bölük, and A. E. Çağlar, "Interrelationships among foreign direct investments, renewable energy, and CO2

emissions for different European country groups: a panel ARDL approach," *Environmental Science and Pollution Research,* vol. 26, pp. 21495-21510, 2019, doi: 10.1007/s11356-019-05415-4.

[16] M. Mert and G. Bölük, "Do foreign direct investment and renewable energy consumption affect the CO2 emissions? New evidence from a panel ARDL approach to Kyoto Annex countries," *Environmental Science and Pollution Research,* vol. 23, pp. 21669-21681, 2016, doi: 10.1007/s11356-016-7413-7.