Analysis of the Impact of Foreign Direct Investment in Renewable Energy on Pollution Emissions in Low-, Middle-, and High-Income Countries in the Middle East

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Citation: Khoz, A., Baghfalaki, A., Peykarjou, K., & Memarnejad, A. (2025). Analysis of the Impact of Foreign Direct Investment in Renewable Energy on Pollution Emissions in Low-, Middle-, and High-Income Countries in the Middle East, *Marketing, and Finance Open*, 2(2), 72-80.

Received: 23 January 2025
Revised: 05 February 2025
Accepted: 14 February 2025
Published: 01 March 2025

Abstract: Environmental issues have been a significant economic concern in both developing and developed economies in contemporary times, highlighting the fact that human activities have inflicted irreversible damage on the planet. Therefore, this study aims to examine this critical issue. The objective of this research is to investigate the effect of factors such as gross domestic product (GDP), healthcare expenditures, foreign direct investment (FDI), energy consumption, and population density on carbon dioxide (CO_2) emissions in Middle Eastern countries over the period 2013–2023. To achieve this, the two-step generalized method of moments (GMM) was employed using EViews 10 software. The research findings indicate that foreign direct investment and energy consumption have a negative and significant effect on pollution emissions, whereas healthcare expenditures have a positive impact.

Keywords: Carbon dioxide emissions, two-step generalized method of moments (GMM), foreign direct investment (FDI).

1. Introduction

Investment in the environment is crucial for preserving natural ecosystems, combating climate change, and ensuring the well-being of future generations. It enhances biodiversity, improves public health, and promotes sustainable economic growth through green technologies and job creation. Additionally, environmental investments can mitigate risks associated with natural disasters, protect air and water quality, and enhance resilience against the adverse effects of global warming, ultimately leading to a healthier planet and a more stable society. Renewable energy plays a vital role in reducing environmental degradation by decreasing reliance on fossil fuels, which significantly lowers greenhouse gas emissions associated with climate change. It promotes cleaner air and water by minimizing pollutants, enhances biodiversity by reducing habitat destruction related to extraction and drilling, and supports sustainable land-use practices [1, 2]. However, the production and installation of renewable energy systems, such as solar panels and wind turbines, can also have environmental impacts, including land-use changes and resource extraction, necessitating careful management and planning to ensure that the transition to renewable energy is both effective and sustainable [3-5].

Several studies have examined the relationship between foreign direct investment (FDI), economic growth, and environmental pollution across different regions using various econometric approaches. Studies investigated the impact of FDI and economic openness on environmental pollution in Iran from 1978 to 2008 using the autoregressive distributed lag (ARDL) model. The findings confirmed a significant positive relationship between FDI and environmental pollution, highlighting the simultaneous effects of economic openness and FDI on pollution levels [6-9]. Others analyzed the effect of oil product intensity, diesel consumption, and gross domestic product (GDP) on CO_2 emissions in Iran's transportation sector from 1996 to 2018 using ARDL estimation. The results indicated that in the long run, oil consumption, product intensity, and GDP had the greatest impact on CO_2 emissions, while in the short run, product intensity did not have a significant effect [10-14].

Thus, the relationship between healthcare expenditures and environmental degradation seems significant, as environmental factors such as air and water pollution, hazardous waste, and climate change can lead to a range of health issues, including respiratory diseases, cardiovascular problems, and increased morbidity rates. Poor environmental quality often results in higher healthcare costs for individuals and governments, as treating these health conditions becomes more urgent and expensive. Moreover, vulnerable populations are disproportionately affected, exacerbating health inequalities and creating a cycle in which impoverished communities bear the burden of both environmental and health challenges, ultimately straining public health systems and resources. Environmental degradation in the Middle East is a pressing issue, characterized by water scarcity, desertification, air pollution, and biodiversity loss. Countries such as Iraq and Syria have suffered from environmental destruction due to conflicts, while nations like Iran face severe water shortages due to mismanagement and climate change [8, 15]. Urbanization and industrialization in Saudi Arabia and the United Arab Emirates have led to significant air quality issues, exacerbated by high temperatures and reduced rainfall. Efforts to address these challenges are often hindered by political, economic, and social factors, leading to ongoing struggles in achieving sustainable environmental policies [4, 8]. The objective of this research is to investigate the effect of factors such as gross domestic product (GDP), healthcare expenditures, foreign direct investment (FDI), energy consumption, and population density on carbon dioxide (CO_2) emissions in Middle Eastern countries over the period 2013–2023.

2. Methodology

To analyze the available statistical data and utilize the findings for policy implications, this study examines data from the period 2013–2023 for ten selected Middle Eastern countries, namely Egypt, Iran, Iraq, Kuwait, Jordan, Oman, Lebanon, Saudi Arabia, Syria, and Turkey. The dependent variable in this study is carbon dioxide (CO_2) emissions. Among the economic variables influencing pollution emissions, independent variables include economic growth, population, foreign direct investment (FDI), energy consumption, and household expenditures. The temporal scope of this research spans from 2013 to 2023, and the study employs data collected for these years. The statistical sample consists of data on gross domestic product (GDP), environmental degradation (measured by CO_2 emissions as a pollution indicator), population growth, healthcare expenditures, energy consumption, and FDI for the ten selected Middle Eastern countries.

For data collection regarding theoretical foundations, literature review, and research background, both Persian and English books, articles, and databases were utilized. The required research data, which consists of secondary data, was obtained from World Bank statistical datasets.

To achieve the objectives of this study, the impact of GDP, FDI, healthcare expenditures, and renewable energy consumption on environmental pollution (CO_2 emissions) in a panel of Middle Eastern countries during the period

2013–2023 was analyzed. The research model follows the study by Khan et al. (2020) and employs the second-generation panel unit root test and the two-step generalized method of moments (GMM). The applied model, based on the conducted analyses and unit root test results, aims to determine the degree of variable integration and ensure the appropriateness of the estimation method. The model used in this study is expressed as follows:

CO2_it = α_i + B1 * FDI_tt + B2 * E_tt + B3 * PG_tt + B4 * GDP_tt + B5 * HC_tt + u_it

Where the variables in the model, from left to right, represent:

- CO_2 emissions (CO2),
- Foreign direct investment (FDI),
- Population growth (PG),
- Energy consumption (E),
- Household healthcare expenditures (HC), and
- Gross domestic product (GDP).

It is important to note that this model suggests that the economy should allocate a portion of its capital to preventing and mitigating environmentally harmful activities. Environmental degradation occurs at every stage because insufficient capital has been allocated in the past to prevent and reduce environmentally damaging activities. The optimal allocation in this context is demonstrated through the applied model.

3. Findings

Descriptive statistics encompass a set of methods used for collecting, summarizing, classifying, and describing numerical facts. In essence, this type of analysis depicts the research data and information, providing an overall pattern or layout of the data for faster and more efficient use.

Table 1. Descriptive Statistics of the Research Variables

Variable	Mean	Minimum	Maximum	Standard Deviation
CO2	2153.32	0.4	0.85	3535.50
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 study variables. The most important central index is the mean, which indicates the equilibrium point or the center of the distribution and is a suitable measure of central tendency. Another descriptive parameter is the standard deviation, which illustrates the dispersion of the data. Moreover, the minimum and maximum values in the table show the range of data variation. The standard deviation is the square root of the average squared distance of each data point from the mean and is an indicator of dispersion.

Before estimating the model, it is necessary to examine the stationarity of its variables. A variable is considered stationary if its mean, variance, and covariance remain constant over time. In general, if shifting the time origin of a variable does not change its mean, variance, or covariance, then that variable is stationary; otherwise, it is non-stationary.

Stationarity of variables is examined in three cases: (at level), (first difference), and (second difference). If the p-value obtained from the test at level is less than 5 percent, the null hypothesis is rejected, and the variable is considered stationary in the model. The stationarity (unit root) test is conducted for each model variable in turn.

Since the time span of this study is relatively long, non-stationarity of variables would create problems in estimation.

Examining the stationarity of variables before proceeding with model estimation is of particular importance. For this purpose, multiple tests have been proposed for panel data, generally classified into first-generation and second-generation tests. First-generation tests assume no cross-sectional dependence in the error term while testing for stationarity. As Pesaran (2004) indicates, this assumption may only hold for panels with a large number of cross-sections. However, when the number of cross-sections is small and the time span is large, cross-sectional dependence in the error term can occur. In that case, first-generation unit root tests lose efficiency, and second-generation unit root tests should be used to assess stationarity.

As shown in the table below, based on the Levin, Lin, and Chu test, all variables are stationary at level I(0). Accordingly, the model can be estimated without concerns about spurious regression.

Table 2. Unit Root Test Results (Levin, Lin, and Chu) (LLC)

Variable	Test Statistic	p-value	Result
CO2	-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, based on the Levin, Lin, and Chu test, all variables are stationary, and there is no need for a cointegration test. However, for verification, the cointegration test is also performed.

Before estimating the model, pre-tests related to each econometric model must be conducted. First, the cointegration between the variables of this study is examined.

From an economic perspective, cointegration means that two or more time series variables, based on theoretical foundations, are related to each other to form a long-run equilibrium relationship. Even though these time series may themselves exhibit random trends (non-stationary), they closely follow each other over time such that their difference is stable (stationary).

Investigating the existence of cointegration in panel data is crucial. If the model's variables are not stationary, the estimation may result in a spurious regression. To prevent this issue, cointegration tests are conducted before model estimation. Once the existence of a long-term relationship is confirmed, the desired model can be estimated.

The concept of cointegration suggests the presence of a long-run equilibrium relationship that the economic system tends toward over time. If the significance level exceeds five percent, the null hypothesis is accepted; otherwise, its alternative hypothesis—indicating cointegration—will be accepted. In this stage, the Pedroni cointegration test is used to examine the long-run cointegration of variables.

Table 3. Pedroni Cointegration Test Results

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

Considering the ADF statistic and its corresponding p-value, the null hypothesis of no cointegration is rejected. Therefore, the dependent variable and the independent variables have a long-term relationship.

In statistics, the variance inflation factor (VIF) assesses the severity of multicollinearity in an ordinary least squares regression. It essentially provides an index indicating how much the variance of the estimated coefficients is inflated due to collinearity. The results showed that this value for all variables is below the commonly accepted standard of ten (10).

Table 4. Examining Multicollinearity Among Variables

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

In this study, Spearman's correlation was used to investigate the correlations among the variables. According to the table below, there is no strong significant correlation among the explanatory variables in the study.

Table 5. Spearman's Correlation Among the Research Variables

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

The Hausman test is employed to determine the type of model (fixed effects or random effects) to use in panel data. It is based on whether there is a correlation between the regression errors and the independent variables of the model. If such correlation exists, the random effects model is appropriate; if not, the fixed effects model is appropriate. The hypotheses are as follows:

H0 = No correlation between the independent variables and the error term (Random effects model is preferred)

H1 = There is correlation between the independent variables and the error term (Fixed effects model is preferred)

First, fixed effects and random effects must be examined.

Table 6. Fixed Effects Estimation Results

Variable	Coefficient	Std. 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; Prop F = 0.010; R^2 = 0.83

Based on the fixed effects results, as can be seen, all the research variables—except for economic growth and population—have a positive and significant effect on the dependent variable (pollution emissions, i.e., carbon dioxide). For instance, if foreign direct investment (FDI) increases by one unit, CO_2 emissions increase by 2.2806 units. After estimating the fixed effects, the random effects model is also examined (though no interpretation is provided here).

Table 7. Random Effects Estimation Results

Variable	Coefficient	Std. 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; Prop F = 0.000; R^2 = 0.42

After estimating the model with both fixed and random effects, the F-Limer test is performed to differentiate between fixed effects and the pooled ordinary least squares method. The results are shown in the following table.

Table 8. F-Limer Test

Test	p-value	Statistic
F-Limer	338.80	0.000

The results indicate that the fixed effects method is preferred over pooled least squares because the p-value is less than 0.05. Hence, panel data is confirmed over pooled data. Finally, the Hausman test is examined.

Table 9. Hausman Test Results

Test	Statistic	Significance	Conclusion
Hausman	349.21	0.000	Reject H0 (random effects) and accept fixed effects model

As indicated above, the Hausman statistic falls in the critical region. Since the p-value is less than 0.05, the null hypothesis (favoring random effects) is rejected, and the fixed effects model is deemed the better choice.

Based on the above discussion, the model is estimated and its coefficients are as follows. According to the table below, there is a negative and significant relationship between foreign direct investment and pollution emissions. The negative interaction effect implied by the FDI coefficient on CO2 emissions indicates that if foreign direct investment is accompanied by increased pollution and reduced environmental quality, it may hinder the path to sustainable development in these economies.

Table 10. Regression Model

Variable	Coefficient	Std. Error	t-Statistic	p-value
Co2(-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 a method used to detect whether the regression error terms are uncorrelated with instrumental variables in econometric studies. If there is correlation between the error terms and instrumental variables, the regression estimators will not be efficient (they will not have the minimum variance), and the model's analysis and statistical inference would be unreliable. For the Sargan test to be confirmed, the statistic with (k-q) degrees of freedom at a 95% confidence level must be compared with the standard chi-square table. If the calculated statistic is less than the tabulated chi-square, the null hypothesis is confirmed, and the model is considered valid. If the significance level exceeds 0.05, the model is validated. Accordingly, as shown in the table below, the estimated model is correct and valid.

Table 11. Sargan Test Results

Test	Test Statistic	p-value
Sargan	28.31	0.077

Since using the first-order differencing method indicates that the error terms follow a first-order autoregressive process, for the Arellano-Bond approach to yield consistent estimators, the error terms must not exhibit second-order autocorrelation. The presence of second-order autocorrelation would invalidate the Arellano-Bond estimates. The test results for first- and second-order autocorrelation are reported in the table below.

Table 12. First- and Second-Order Autoregressive Test Results for the Panel Data Model (Arellano-Bond Test)

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, indicating that the null hypothesis of no second-order autocorrelation among the error terms is not rejected. Consequently, the results confirm that using panel data is appropriate.

Based on the data analysis, each research hypothesis is summarized as follows:

In the first hypothesis—"There is a significant relationship between foreign direct investment and pollution emissions in Middle Eastern countries"—the results show a negative effect of FDI growth on $CO2$ emissions.

In the second hypothesis—"There is a significant relationship between energy consumption and pollution emissions in Middle Eastern countries"—the findings indicate a negative effect of energy consumption on $CO2$ emissions; hence, this hypothesis cannot be rejected.

Regarding the third hypothesis—"The effect of population density on pollution emissions and their relationship in Middle Eastern countries"—population growth has a positive and significant impact on pollution emissions. Because the results show that population density positively influences $CO2$ emissions, this hypothesis cannot be rejected.

The next hypothesis concerns the "positive effect of GDP on pollution emissions in Middle Eastern countries." Based on the model estimates, GDP positively influences pollution emissions; thus, this hypothesis also cannot be rejected.

1. **How does investment in renewable energy affect environmental quality in the Middle East?**: The relationship between foreign direct investment and pollution emissions is negative. If investment increases by one unit, environmental pollution decreases by 3.77 units.
2. **How does economic growth affect pollution indices in Middle Eastern countries?**: There is a direct, positive relationship between these two variables. With an increase in GDP, pollution emissions grow, specifically, a one-unit rise in GDP reduces environmental quality by 214.4 units.
3. **How do industrialization and energy efficiency impact pollution emissions in Middle Eastern countries?**: There is an inverse relationship between energy consumption and pollution emissions. An increase of one unit in energy consumption reduces pollution by 22.6 units.

4. **How does population growth affect pollution in Middle Eastern countries?**: Population growth has a positive effect on pollution emissions in this study. An increase of one unit in population raises pollution by 209.9 units.

4. Discussion and Conclusion

In recent years, pollutant emissions, particularly carbon dioxide (CO_2), have become one of the major environmental challenges facing developing countries. Carbon dioxide, accounting for 60% of greenhouse gas effects, is a key contributor to climate change. As a result, it is used as the primary benchmark for measuring the impact of other gases on climate change, with their global warming potential assessed relative to CO_2. In recent decades, increasing attention has been given to pollution generated by economic activities as a byproduct of development, making it a major concern among economists. The current state of the global environment highlights the fact that human activities have caused irreparable damage to the planet.

To analyze the available data and apply the findings at the national level, this study utilized statistical data from the period 2013–2023 for ten selected Middle Eastern countries, namely Egypt, Iran, Iraq, Kuwait, Jordan, Oman, Lebanon, Saudi Arabia, Syria, and Turkey. Initially, the study examined the descriptive statistics of the research variables. The stationarity of the research variables—including healthcare expenditures, foreign direct investment (FDI), population density, energy consumption, gross domestic product (GDP), and carbon dioxide emissions—was tested using the Levin, Lin, and Chu (LLC) test, confirming that all variables were stationary. Based on the model selection strategy outlined in Chapter Three, and using EViews 10 software, the Hausman test was conducted, with a p-value of 0.000, leading to the selection of the fixed effects model. The research model, aligned with prior research [5, 7, 8, 16], applied second-generation panel unit root tests and the two-step generalized method of moments (GMM) approach. The results indicated that foreign direct investment and energy consumption have an inverse relationship with carbon dioxide emissions.

Given the scarcity and dispersion of energy consumption data—one of the key limitations of this study—it is recommended that a comprehensive energy consumption database be developed in Middle Eastern countries, accompanied by analytical and qualitative studies on these data. According to the findings of this research, energy consumption, population density, and foreign direct investment are the most significant factors influencing carbon dioxide emissions. Future research could further explore the impact of technology on pollutant emissions across different economic sectors and examine the effects of renewable energy on environmental sustainability.

Authors' Contributions

Authors equally contributed to this article.

Ethical Considerations

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

Acknowledgments

Authors thank all participants who participate in this study.

Conflict of Interest

The authors report no conflict of interest.

Funding/Financial Support

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

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