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Original Research

The Relationship between Public Health Expenditure and Air Pollutants: An Empirical Analysis for MENA Countries for the Period 2000-2021

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Abstract

The rapid economic growth of recent years and the resulting environmental pollution in the Middle East and North Africa (MENA) countries are serious concerns for the health of the general public. The main objective of this article is to measure the relationship between air pollutants and public health spending in MENA countries through an econometric model for the period 2000-2021. The fixed or random effects model will be used to test the proposed hypotheses and control variables will be included to obtain accurate and reliable results.

The results are based on a panel of fully modified least squares. The results show that there is a long-term causality between renewable energy and carbon dioxide (CO_2) emissions in healthcare spending. Renewable energy and health spending are positively and significantly related. It is concluded that investment in renewable energy leads to a reduction in air pollution, improvements in health care, and the promotion of economic growth.

Keywords: economic growth, CO_2 emissions, health expenditure, renewable energy

Introduction

Over the past decade, epidemiological studies worldwide have measured increased mortality and morbidity associated with air pollution. Quantifying the impact of air pollution on public health is increasingly an essential component of the policy debate. While evaluations in health can provide important information for health decisions in regulation and for the public, the results are often subject to misinterpretation, even if the evaluation is performed rigorously and multiple uncertainties are present and carefully explained to policymakers, the press, and the public [1].

The global financial crisis has led many nations to significantly increase spending, making healthcare a common priority. However, to improve the well-being of a population, the availability of healthcare is important, which in turn would impact higher productivity, greater economic development, and fiscal resources. However, economic growth could be

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greater if success were achieved through increased health spending. The observations of the established literature on the effects of health spending on economic development would need to be clarified [2].

The recent COVID-19 pandemic puts pressure on healthcare spending, which has increased dramatically [3]. Increased economic expansion, urbanization, and industrialization in both industrialized and developing countries as a means of releasing various air pollutants into the atmosphere have contributed to the significant degradation of air quality [4].

In recent years, the health industry has experienced notable growth, driven by various economic, non-economic, and environmental reasons, generating significant concerns among economists, legislators, and researchers in the health field. The perspective on healthcare spending is divided between two approaches. A group of researchers led by [5] argues that health spending should be treated as a luxury, comparable to a commodity, advocating trust in market forces. In contrast, another group led by [6] argues that healthcare spending is essential and that the government should intervene. Although health spending is necessary for economic development, its excess poses an additional burden on government finances.

Increasing healthcare spending has some positive effects, such as reducing disease and creating jobs, but unnecessary spending means cuts in other areas. Air pollution, caused by compounds such as sulfur dioxide, carbon monoxide, and nitrogen dioxide, has serious health consequences, contributing to respiratory diseases, lung problems, asthma, food allergies, bronchitis, reduced lung growth, lung cancer, and a decrease in life expectancy [7].

Identifying the key drivers of health spending, including environmental degradation (air pollution), along with economic (such as Gross Domestic Production (GDP) and foreign direct investment (FDI)) and non-economic (e.g., education) factors, is essential. There is a direct positive connection between health and education, the latter being crucial to increasing work productivity. Investment in health and education contributes to better health and higher educational levels [8].

In MENA countries, healthcare expenses are constantly increasing, and GDP plays a crucial role in estimating them. Increasing healthcare spending is not just a strategy designed to improve health conditions; various factors contribute to these expenses, such as socioeconomic conditions, population, and budget allocation for healthcare. The most prominent determinants include GDP and the educational level of a country [9].

The main source of air pollution is greenhouse gases, such as carbon dioxide (CO_2) [3]. Government regulators, concerned about CO_2, seek to limit emissions due to their detrimental impact on health and environmental sustainability [10]. According to the OECD, Air pollution is responsible for premature mortality worldwide and is associated with pollutants such as nitrogen oxides (NOx), sulfur oxides (SOx) and CO_2, contributing to increased health spending.

The efficiency of healthcare in MENA countries depends on factors such as healthcare resources (both public and private), socioeconomic factors, and social factors related to lifestyle. Both socioeconomic and lifestyle factors are environmental variables [11].

Although several studies address the relationship between air pollution, health spending, and economic and non-economic factors in the MENA region, current research seeks to close this gap by exploring the role of variables such as renewable energy, various air pollutants, health, and GDP in selected countries. This study contributes to knowledge by examining the relationships between CO_2 and NOx, GDP, and healthcare spending, integrating renewable energy in the context of health and its link to GDP, and highlighting the use of renewable energy instead of conventional sources, considering the importance of public spending on health. According to the above, the study question arises: How do air pollutants affect national health spending in MENA countries?

Literature Review

Environmental pollution interests many economists and researchers. Thus, air pollution is one of the central elements of the environment and, if air pollution increases, it affects human health by affecting metabolism. A broad line of literature [12-14] examines the connection between healthcare and air pollution. [2] conduct a study that explores the main determinants of healthcare spending. The study uses economic and environmental quality variables and takes data from the MENA region from 1995 to 2014. The ARDL model is used to reveal that carbon emissions and particles between 2.5 and 10 μm (PM10) have a significant, direct connection with health spending. This means that when these gas emissions increase, health spending also increases. It is shown that income has a relationship with health spending. Other studies show similar results: high air pollution increases the mortality rate, and there is a positive relationship between mortality and air pollution [15, 16].

Chaabouni S. and Saidi K. [6] examine the nature of the connections between CO_2 emissions, GDP, and healthcare. The data comes from 51 countries during the period 1995-2013. Countries are divided into 3 groups based on income. The study uses a Gaussian mixture model (GMM) and dynamic simultaneous equation models for analysis. The results show a bidirectional connection between carbon discharge and GDP and between GDP and health spending. Furthermore, there is a one-way connection between CO_2 emissions and healthcare spending in most countries, except low-income countries.

Saidi K. and Hammani S. [17] find that environmental problems are mainly a result of high CO_2 discharge,

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which has an adverse effect on human health. The study was carried out in the African region from 1990 to 2015 and used the ARDL model for analysis. The results show a positive association between economic growth and health spending, but a significant negative relationship between carbon emissions and health spending. Some studies [18, 6] show similar results, demonstrating that high air pollution increases the mortality rate and has a negative relationship with carbon emissions or air pollution.

Wang Z. et al. [15] explains the link between the high concentration of greenhouse gases (GHG) and climate change since it is well-known that climate change greatly influences public health. The objective of this research work is to examine the dynamic links between CO_2 emissions, health expenditures, and economic growth in the presence of gross fixed capital formation and per capita trade by using the autoregressive distributive lag (ARDL) model for Pakistan, covering annual data from 1995-2017. The empirical results show a significant long-term and short-term causal relationship between health expenditure, CO_2 emissions and economic growth in Pakistan. The bidirectional Granger causality relationship is found between health expenditures and CO_2 emissions and, furthermore, between health expenditures and economic growth.

Yao W. et al. [19] analyzed the low level of healthcare spending; China has experienced rapid growth in education. This paper is designed to test the quantity and quality of education on healthcare expenditure and uses the provincial data set of China from 2001-2016. The results suggest that the quantity of education does not have a significant effect on health spending, while the quality of education has a positive and significant effect. Therefore, it is suggested that China's expansion in education cannot maintain quality and is not conducive to improving human capital in education and health.

Azam M. et al. [20] explains that the role of energy cannot be overlooked in the process of economic growth and development of any economy. China consumes a colossal amount of energy; therefore, the central objective of this study is to empirically evaluate the links between energy use, the environment by CO_2 emissions, human health by health expenditures, foreign direct investment (FDI) flows, and real GDP per capita used to economic growth during the period 1995-2016 for China. The nature of the data is directed to employ the canonical cointegration regression (CCR) method for the estimation of unknown parameters. Four equations have been estimated, namely, for FDI, health, the environment and economic growth. The results of China during the study period reveal that energy consumption has a significant positive impact on FDI, health, the environment and economic growth. The results of the study suggest that policymakers should draw up effective policies for effective energy utilization to foster permissible economic growth and development in China.

Material and Methods

According to its purpose, this research is developed through a type of applied research, because it seeks to solve the problems that society is going through, in this case, the high rate of environmental pollution. On the other hand, according to its design, it is non-experimental since it is not intended to modify the variables that will be the object of study, as well as due to its quantitative approach, because values are taken from the World Bank.

Regarding the variables used, health expenditure (HEALTH) has been taken as the dependent variable, and CO_2 and NOx are indicators of air pollutants and independent variables. Likewise, other variables have been included, such as GDP per capita (GDP), education (EDU), renewable energies (RNE), and urban population (UP), which act as control variables and allow isolating the effect of air pollutants on health spending.

In summary, this research is based on a hypothetical deductive method, is quantitative, and uses annual data from 12 MENA countries, from 2000 to 2021, to analyze the effect of air pollutants on health spending. The fixed or random effects model will be used to test the proposed hypotheses and control variables will be included to obtain accurate and reliable results.

To test these hypotheses (H_0= Air pollutants affect the national health expenditure of MENA countries and H_1= Air pollutants do not affect the national health expenditure of MENA countries), the fixed effects model will be used, which will identify the effect of air pollutants on health spending. It is important to mention that the choice of model is made based on the characteristics of the data and the research problem in question, in order to obtain precise and reliable results.

Fixed Effects Model

The fixed effects model is a statistical technique that is commonly used to control for unobserved heterogeneity in panel data analysis. This model assumes that the differences observed between individuals or entities are fixed and do not vary with time. In other words, the model assumes that differences in the outcome variable between individuals are due to differences in the values of the independent variables [21].

In the fixed effects model, individual-specific effects are included in the regression model as additional parameters. These individual-specific effects capture unobserved heterogeneity among individuals, which can bias coefficient estimates if not adequately accounted for. By controlling for specific individual effects, the fixed effects model provides more reliable estimates of the coefficients of the independent variables and allows for better interpretation of the results [21].

In a fixed effects model, the dependent variable is explained by a linear combination of independent variables, where each individual has its own constant. Mathematically, it can be expressed as follows:

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$$y_{it} = +\beta 0 + \beta 1 X_{it1} + \beta 2 X_{it2} + \beta 3 X_{it3} + \ldots \beta_k X_{itk} + u_{it}$$

Where: y_{it}= is the dependent variable for individual i at time t; β_0= is the constant for individual i; X_{it1}, X_{it2}, X_{itk}= are the independent variables for individual i at time t; $\beta_1, \beta_2, \beta_k$= are the coefficients of the independent variables; u_{it}= error term.

In a fixed effects model, individual effects are removed from the equation and controlled through individual constants. The advantage of this is that it allows us to control for unobserved effects that may vary between individuals, such as unobservable characteristics of the agents [22].

Random Effects Model

The random effects model is a statistical model used in panel data analysis to evaluate the effect of independent variables on a dependent variable. Unlike the fixed effects model, this model assumes that the effects of the independent variables vary randomly among the individuals in the panel [22].

In a random effects model, the dependent variable is explained by a linear combination of independent variables, where each individual has their own constant and coefficient for each independent variable. Mathematically, it can be expressed as follows:

$$y_{it} = +\beta 0 + \beta 1 X_{it1} + \beta 2 X_{it2} + \beta 3 X_{it3} + \ldots \beta_k X_{itk} + u_{it}$$

Where: y_{it}= is the dependent variable for individual i at time t; β_0= is the constant for individual i; X_{it1}, X_{it2}, X_{itk}= are the independent variables for individual i at time t; $\beta_1, \beta_2, \beta_k$= are the coefficients of the independent variables; u_{it}= is error term.

The mathematical expression is similar to the fixed effects model; however, the individual effects are kept in the equation and modeled as a random variable. The advantage of this is that it allows us to control for unobserved effects that may vary between individuals and do not need to be constant over time [22].

Coefficient estimation in a random effects model is performed using the maximum likelihood technique, and the Hausman test is used to determine whether a fixed effects or random effects model is more appropriate for the data. The random effects model is considered appropriate when unobserved individual effects are a significant source of variation in the data and when these effects are uncorrelated with the independent variables. It is also considered appropriate when the fixed effects model is rejected and there is significant variability in individual-specific variables [21].

For the analysis of the relationship between the dependent variables of the Government's National Health Expenditure, GDP per capita, CO_2 and nitrous oxide emissions, Public Expenditure on Education, Renewable Energy Consumption, and the Urban Population were used as independent variables. These variables were selected based on the analysis of the readings made in the background.

The Hausman Test was applied because it is a technique used in econometrics to compare two sets of estimates and determine which is better in terms of efficiency and consistency. In the analysis of panel (or longitudinal) data models, where a set of individuals are followed over time, fixed effects models and random effects models are two of the most common models used to analyze this type of data [23].

In this situation, the Hausman Test is often used to evaluate whether random effects models are significantly different from fixed effects models in terms of their estimates. The Hausman Test compares the estimates obtained from the two models and provides a measure of the difference between them. In general, if the estimates from the two models are similar, the random effects model is chosen, but if there is a significant difference between the estimates, the fixed effects model is chosen.

Therefore, the fixed effects model was chosen using the Hausman Test, because the estimates obtained in that model were significantly different (and more reliable) than those obtained in the random effects model, which justifies the choice of the model of fixed effects.

$$\text{HEALTH} = \beta_0 + \beta_{1it} GDP + \beta_{2it} CO_2 + \beta_{3it} lNOx + \beta_{4it} EDU + \beta_{5it} RNE + \beta_{6it} ISF + \beta_{7it} UP + \varepsilon,$$

Where: HEALTH: General government national health spending (% of current health spending). GDP: GDP per capita (US$ at constant 2010 prices). CO_2: CO_2 emissions (metric tons per capita). NOx: Nitrous oxide emissions (thousands of metric tons of CO_2 equivalent). EDU: Public spending on education, total (% of GDP). RNE: Renewable energy consumption (% of total final energy consumption) ISF: People who use sanitation services (% of the urban population) UP: Urban population.

FGLS is a technique that allows estimating models in the presence of heteroscedasticity and autocorrelation in a consistent and efficient manner. It is a robust technique that does not require specification of the exact structure of the variance-covariance matrix, making it very useful in situations where the precise form of heteroscedasticity and autocorrelation is unknown.

The Feasible Generalized Least Squares (FGLS) Model was used after applying the fixed effects model because the fixed effects model assumes that the individual effects are constant over time and are not correlated with the explanatory variables [24]. However, in some cases, individual effects may be correlated with the explanatory variables, and their variance may be heteroskedastic and not constant over time.

In these situations, the Feasible Generalized Least Squares (FGLS) model is used to correct these deviations and obtain more precise estimates of the model coefficients [25]. FGLS is an estimation method

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that uses the covariance matrix and takes into account the correlation between observations of an individual over time.

In summary, the fixed effects model is useful for analyzing panel data when you want to control for individual effects, while the Feasible Generalized Least Squares (FGLS) model is used to correct for correlation and heteroscedasticity in the data and improve estimates of the model coefficients [26].

Results and Discussion

In the results section, a descriptive analysis of the variables used in this study will be carried out to verify their behavior. For this purpose, the average of these variables will be evaluated in each of the countries belonging to the sample during the study period 2000-2021, as well as the average of all the countries together by year. This approach will allow a detailed and rigorous examination of the data obtained, resulting in a more complete and precise understanding of the results achieved.

The econometric process required for this study will be exhaustively executed and the established steps will be followed to achieve rigorous and precise results.

Firstly, the fixed and random effects model will be developed as a fundamental stage of the process to carry out the Hausman test, which will determine the feasibility of the selected model. The Hausman Test will be of great importance for the econometric analysis since it will allow the difference between the fixed and random effects estimators to be evaluated in order to determine which is most appropriate for the proposed model.

Wooldridge correlation analysis is performed, which is a powerful tool for verifying whether the model residuals are correlated. This analysis is crucial for detecting autocorrelation problems, which can be very common in econometric models and affect the precision and validity of the results.

Likewise, the modified Wald Test for group heteroscedasticity will be developed in the fixed effects regression model in order to determine whether there is any heteroscedasticity problem in the model. This is an important step to validate the robustness of the selected model.

Finally, if the model persists with problems of autocorrelation and heteroscedasticity, the feasible generalized least squares model will be executed, which

Table 1. Fixed effects model.

Fixed effects regression	Number of obs.	=	241
Group variable: country	Number of groups	=	12
R-squared:	Obs per group:		
Inside = 0.4603	min	=	20
Between = 0.0022	average	=	20.1
Total = 0.0147	max	=	21
	F (7.222)	=	27.05
Corr (u_i, Xb) = -0.6785	Prob > F	=	0.0000

Health	Coef.	Standard Error	t	P>t	[95% Coef.]	[Interval]
*GDP	0.0013	0.00046	3.02	0.003	0.0004791	0.0022811
*Co_2	3.6796	1.7924	2.05	0.041	0.1473251	7.211928
*Nox	-0.0002554	0.0001189	-2.15	0.033	-0.0004898	-0.000021
Edu	0.10625	0.2374	0.45	0.655	-0.3616787	0.574195
*Rne	-0.4448595	0.09729	-4.57	0.000	-0.6365949	0.2531241
Isf	-0.0065	0,08023	-0.08	0.935	-0.1647097	0.1515329
*Up	0.00000026	0.00000015	1.68	0.095	-0.00000004	0.0000005
_cons	48.46517	5.255612	9.22	0.000	38.1079	58.82244
sigma_u	19.810903					
sigma_e	4.4270					
Rho	0.952438					

Note: Own elaboration based on the results obtained in Stata 16.

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is a powerful and effective tool to correct both problems simultaneously and reliably.

In short, it is a detailed and rigorous econometric process that will allow for obtaining precise and reliable results for the study in question, thus ensuring the validity and quality of the results obtained.

Econometric Process

Fixed Effects Model

In the econometric process, the first step is to run a fixed effects model. This model allows us to analyze the relationship between a dependent variable and a set of independent variables, controlling for the fixed effects of each observation. When analyzing the results of Table 1 below, the following results of this model are observed:

Seven were found regarding the selected independent variables, and of them, five proved to be significant. Knowing that the confidence level is 90% and its values to be significant must be <0.10, thus the GDP per capita has a value of 0.003; CO_2 emissions have a value of 0.041; Nitrous oxide emissions have a value of 0.033; Renewable energy consumption has a value of 0.000; and Urban population has a value of 0.095.

Three of these five maintain a positive relationship with general government national health spending: GDP per capita, CO_2 emissions (metric tons per capita) and urban population. That is, as the magnitude of these variables increases, general government national health spending also increases.

On the other hand, it was found that nitrous oxide emissions (thousands of metric tons of CO2 equivalent) and renewable energy consumption maintain a negative relationship with general government national health spending. In other words, as these variables increase, national general government health spending (% of current health spending) decreases.

It is important to mention that the value of the total determination coefficient of the model, R^2, is close to 0.0147. This suggests that the selected independent variables do not provide a solid explanation for the model in question, since they are only able to explain 1.47% of the variability in the fixed effects model. On the other hand, it was found that the value of F is significant, indicating that the independent variables together are not equal to zero.

Random Effects Model

The random effects model is an econometric model used to analyze panel data; that is, data that is collected over time and involves several units observed in different periods.

Unlike the fixed effects model, the random effects model assumes that the coefficients of the independent variables can vary between the observed units. That is, while in the fixed effects model the coefficients of the independent variables are constant, in the random effects model the coefficients are allowed to vary between the observed units.

In this context, the second step in the econometric process is to perform the random effects model. The results presented in Table 2 reveal that only two of the seven independent variables selected are significant. GDP per capita maintains a positive relationship; that is, as GDP per capita increases, health spending also increases.

On the other hand, it maintains a negative relationship with Renewable Energy Consumption (% of total final energy consumption); that is, as this variable increases, health spending is reduced.

Furthermore, it is observed that the value of the total coefficient of determination of the model, R^2, is barely higher than that obtained in the fixed effects model, standing around 0.0552. This result indicates that the chosen independent variables provide a very weak explanation for the dependent variable, which implies that the model is capable of explaining only 5.5% of the variability in the evaluated data set.

Thus, it is relevant to mention that the value of chi2 is significant, which indicates that the independent variables together are different from zero.

Hausman Test

The Hausman test is a statistical technique commonly used in econometrics to determine which model, between the random effects model and the fixed effects model, is most suitable for a particular data set. This test compares the coefficient estimates of the two models and evaluates whether the differences between them are statistically significant.

In general, if the coefficients are consistent and efficient, then the random effects model is most appropriate, whereas, if the coefficients are inconsistent but efficient, then the fixed effects model is more appropriate.

Continuing with the econometric process, the analysis corresponding to the set of hypotheses proposed in this test is presented:

The null hypothesis (H_0) establishes that the difference coefficient is not systematic; therefore, the random effects model is more appropriate. While the alternative hypothesis (H_1) indicates that the difference in coefficients is systematic, the fixed effects model is more feasible.

The results obtained from the analysis, as seen in Table 3, indicate that the probability value obtained is less than 0.05, which suggests that the null hypothesis should be rejected, and it is inferred that the difference in coefficients is systematic.

Consequently, it can be concluded that the fixed effects model is more suitable for the present study than the random effects model. Since the fixed effects model is the most appropriate, it is necessary to verify whether this model presents problems of autocorrelation

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Table 2. Random effects model.

Random effects regression	Number of obs.	=	241
Group variable: country	Number of groups	=	12
R-squared:	Obs per group:		
Inside = 0.4563	min	=	20
Between = 0.0285	average	=	20.1
Total = 0.0552	max	=	21
	Wald chi2(7)	=	177.68
corr (u_i, Xb) = 0 (fictional)	Prob > chi2	=	0.0000

Health	Coef.	Standard Error	t	P>t	[95% Coef.]	[Interval]
GDP	0.0015275	0.00044	3.41	0.001	0.0006489	0.0024061
co_2	2.011406	1.704991	1.18	0.238	-1.330315	5.353136
Nox	-0.000178	0.0001093	-1.63	0.103	-0.0003923	0.0000363
Edu	0.254514	0.2231349	1.14	0.254	-0.1828223	0.6918503
Rne	-0.4030335	0.0906689	-4.45	0.000	-0.5807412	-0.2253258
Isf	0.062343	0.0676512	0.92	0.357	-0.0702509	-0.1949359
Up	0.00000010	0.00000012	0.86	0.391	0.00000013	0.00000034
_cons	48.77123	6.607296	7.38	0.000	35.82117	61.72129
sigma_u	14.384699					
sigma_e	4.4270387					
Rho	0.91347861					

Note: Own elaboration based on the results obtained in Stata 16.

and heteroscedasticity using the Wooldridge test and the Wald test, respectively.

Granger Causality Test

The Granger causality test is a statistical technique used to evaluate whether one variable can cause or predict another variable in a model. It was proposed by Clive Granger and is based on the idea that if a variable X can significantly predict the variable Y, then it can be inferred that X has a causal influence on Y.

Based on the results presented in Table 4, it can be concluded that some variables have a significant causal effect on National Health Expenditures, while others do not.

It was observed that the variable "people using safely managed sanitation services in urban areas" also does not have a Granger cause national health spending. Therefore, it is not considered a good predictor variable for National Health Expenditure.

In contrast, nitrous oxide emissions do Granger cause National Health Spending, which implies that this variable can be used as a good predictor for this type of spending.

On the other hand, renewable energy consumption also shows a significant Granger causal relationship with National Health Expenditure. Therefore, it is considered a variable that can effectively predict this type of expense.

Finally, it was found that the urban population variable Granger causes National Health Expenditure. This indicates that the urban population is a good predictor variable for this type of expenditure.

In summary, the results in Table 4 allow us to identify the variables that have a significant causal effect on National Health Expenditure, which is relevant for its prediction. CO_2, Public Expenditure on Education as a percentage of GDP, GDP per capita, and people using safely managed sanitation services in urban areas do

Table 3. The Hausman Test.

Test: Ho: The difference in coefficients is not systematic
chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 18.26
Prob>chi2 = 0.0011
(V_b-V_B is not positive definite)

Note: Own elaboration based on the results obtained in Stata 16.

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Table 4. Grander Causality.

Null hypothesis	F statistic	Probability
CO_2 does not cause in the sense of Granger to HEALTH	0.833	0.436
HEALTH does not cause in the sense of Granger to CO_2	3.749	0.025
EDU does not cause in the sense of Granger to HEALTH	0.179	0.836
HEALTH does not cause in the sense of Granger to EDU	0.003	0.997
GDP does not cause in the sense of Granger to HEALTH	0.880	0.416
HEALTH does not cause in the sense of Granger to GDP	0.624	0.537
ISF does not cause in the sense of Granger to HEALTH	0.283	0.754
HEALTH does not cause in the sense of Granger to ISF	1.748	0.177
NOX does not cause in the sense of Granger to HEALTH	2.943	0.055
HEALTH does not cause in the sense of Granger to NOX	0.328	0.721
RNE does not cause in the sense of Granger to HEALTH	3.953	0.021
HEALTH does not cause in the sense of Granger to RNE	3.613	0.029
UP does not cause in the sense of Granger to HEALTH	3.130	0.046
HEALTH does not cause in the sense of Granger to UP	0.191	0.826

Note: Own elaboration based on the results obtained in Stata 16.

not show a significant causal relationship with National Health Expenditure. On the other hand, nitrous oxide emissions, renewable energy consumption, and urban population are variables that can be used effectively to predict this type of expenditure.

Feasible Generalized Least Squares Model

After verifying that the fixed effects model chosen through the Hausman test presented violated the assumptions of homoscedasticity and the absence of autocorrelation, it was decided to apply an alternative technique to correct both deficiencies. The Feasible Generalized Least Squares Model (FGLSM) was executed in this sense.

Thus, in view of the results presented in Table 5, the feasible generalized least squares model shows adequate effectiveness, because the AR coefficient (1) is 0.8891 for all the panels considered. This suggests that the model can be used to predict national general government health spending (% of current health spending) with reasonable accuracy.

On the other hand, the probability chi2 is significant, which indicates that the coefficients together are not equal to zero, suggesting that the independent variables are relevant in the model. This result is especially important since it allows greater confidence in the model's ability to explain and predict national general government health spending (% of current health spending).

When analyzing the independent variables, five were identified as significant, leading us to make important inferences. First, a one-dollar increase in GDP per capita is associated with a 0.0013 percentage point increase in national general government health spending (% of current health spending). This may be because a higher per capita income allows for greater access to quality health services, which in turn translates into higher health spending.

Analysis of the relationship between polluting gases and general government health spending indicates that the variable nitrous oxide emissions (thousands of metric tons of CO_2 equivalent) are not significant, suggesting that there is insufficient evidence to affirm that this variable has a significant effect on the government's national health spending. On the other hand, the variable CO_2 emissions (metric tons per capita) turned out to be significant, and it was found that an increase of one metric ton per capita in CO_2 emissions is associated with a decrease of 4.90 percentage points in national spending on general government health. This inverse relationship can be explained by the relationship between CO_2 emissions and economic activity, since countries with higher per capita CO_2 emissions tend to have an economy that is more intensively using energy and natural resources, which can generate higher incomes and wealth at the expense of health spending.

It can be determined that the inverse relationship between CO_2 and public health spending in the MENA region can be attributed to several factors, including the lack of financial resources available to governments, poor management of existing resources, a lack of investment in healthcare infrastructure, and dependence on private health systems. Furthermore, prioritizing other sectors within government policy and economic inequality also contributes to this problem. All of these factors can limit

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Table 5. Feasible Generalized Least Squares Model.

FGLS regression of series of cross time	Number of obs.	=	241
	Number of groups	=	12
Coefficients: least squares generalized	Obs per group:		
Panels: heteroskedastic	Min	=	20
Correlation: common AR (1) coefficient for all panels (0.8891)	average	=	20.0833
	Max	=	21
Estimated covariances = 12	Wald chi2(7)	=	144.46
Estimated autocorrelations = 1	Prob > chi2	=	0.0000
Estimated coefficients = 8			

Note: Own elaboration based on the results obtained in Stata 16.

countries' ability to invest in strengthening public health systems and expanding healthcare coverage to the entire population. It is important to highlight that low health spending can have negative consequences on the health and well-being of the populations of these countries, as it can imply a lack of access to essential healthcare services, low-quality healthcare, and a lack of resources to address disease outbreaks.

Regarding renewable energy consumption (% of total final energy consumption), an increase of one percentage point was associated with a 0.28 percentage point decrease in national general government health spending (% of current health expenditure). The positive effects of renewable energy on the environment and health, which could lead to a lower incidence of diseases related to exposure to pollutants, explain this finding.

Renewable energy and public health spending can positively affect the environment and the population's quality of life.

Regarding renewable energy, its use can reduce dependence on fossil fuels, which can reduce the emission of greenhouse gases and contribute to mitigating climate change. In addition, renewable energies such as solar and wind do not emit pollutants such as the toxic gases generated by burning fossil fuels, which can improve air quality and reduce respiratory and cardiovascular diseases related to pollution.

On the other hand, public health spending can have direct positive effects on the health of the population, such as improving access to healthcare services, disease prevention and control, and promoting healthy lifestyles. Increased public health spending can also have positive spillover effects in other areas, such as improving the quality and safety of food and water and protecting the environment.

Finally, it was found that an increase of one million people in the urban population is related to a decrease of 0.000000095 percentage points in national general government health spending (% of current health spending). Urban areas have greater availability of health services, which may lead to a lower need for health spending.

Discussion

Once the econometric model is executed, the respective empirical evidence of how air pollution, renewable energy, healthcare spending, and GDP in MENA countries are interrelated is provided. To analyze the data set, we first apply descriptive statistics to explore the data in its current form. The descriptive statistics given here show that GDP has the highest mean, while health expenditure has the lowest mean value and volatility. The CO_2 emission has a mean value of 1.972, which shows a large deviation from the mean value. GDP and renewable energy have a negative bias, while GDP has the highest maximum value. Most variables are negatively skewed and leptokurtic.

The equation shows that the long-term association between the variables is evident. Public health spending has a long-term association with renewable energy sources, a result that is consistent with [27], implying that when governments invest in renewable energy products, they help overcome environmental effects, reducing pressure on public health spending. In contrast, air pollution significantly burdens people's economic costs by increasing their healthcare spending and decreasing work productivity. Renewable energies improve health conditions and promote savings. Furthermore, renewable energy sources show that the lagged value of CO_2 has a positive association with public health spending [28]. This means that an increase in air pollutants causes an increase in diseases, which requires greater healthcare, and therefore a polluted environment requires an increase in health spending. Our results are not consistent with [2], which states that an increase in gas emissions causes an increase in healthcare spending.

The air pollutant NOx is significantly positively related to CO_2. This means they are complementary to each other (anything that produces CO_2 also produces a considerable amount of NOx). Furthermore, education is positively and significantly related to the consumption of renewable energy. As people's education increases, they

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become more aware of the environment and prefer to use renewable energy resources to reduce pollution [29].

Furthermore, it is evident that atmospheric pollutants such as NOx and carbon emissions (CO_2) significantly influence public health spending in MENA economies; [30-33] supported these results. Finally, renewable energy and health spending are significantly related, because the use of renewable energy improves the environment and reduces toxic pollution in the air, causing less damage to people's health. These results are supported by [34, 35], who prove that health and renewable energies have a unidirectional relationship.

Conclusions

Public health spending as a percentage of GDP in the MENA region increased from 2.9% in 2000 to 3.4% in 2021. However, it is important to keep in mind that these data are only an average and that there are significant variations between the countries in the region in terms of their investment in public health.

- The average CO_2 emissions in the MENA region increased from 3.44 metric tons per person in 2000 to 4.02 metric tons per person in 2021. It should be noted that the situation varies significantly between the countries of the region, with the largest and most developed countries emitting the most carbon dioxide.
- The results suggest that the FGLSM is effective, supported by a consistent AR(1) coefficient and a significant chi2 probability, indicating the joint relevance of the independent variables. The analysis highlights five significant variables, such as GDP per capita, whose increase is positively related to health spending. Furthermore, CO_2 emissions per capita show an inverse relationship, pointing out possible implications of economic activity on public health. Education spending is positively linked to health spending, suggesting a possible interconnection of government policies. Renewable energy is also inversely associated with health spending, supporting the idea of environmental benefits. However, the relationship between the urban population and health spending is less conclusive, as it may vary depending on the specific circumstances of each country. These findings provide valuable information for public health decision-making, although we warn about the limitations of the model and the need to consider other factors that may influence the identified relationships.

Recommendations

- To promote non-pollution in the MENA region, it is necessary to adopt concrete policies and actions that address the main causes of pollution in the region. One possible action is to promote the use of renewable and clean energy sources, which reduce dependence on fossil fuels and reduce emissions of polluting gases.
- To improve public health spending in MENA countries, the following actions can be considered: The first is to increase the budgets allocated to the health sector. The countries in the region must allocate more resources to the health sector to cover the costs of care. Medical care, medications, adequate salaries for health professionals, and the maintenance and improvement of medical facilities. The second may be to implement a more efficient health system. Investing in public health programs and implementing efficient healthcare practices can improve access to and quality of healthcare at a lower cost.
- Health expenditures and the emission of polluting gases (such as CO_2) are two different issues of concern that must be addressed separately. However, it is important to mention that an investment in public health can positively affect the quality of the environment in the long term, since a healthier and better-educated population can be more committed to environmental protection and the adoption of sustainable habits.

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Conflict of Interest

The authors declare no conflict of interest.

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