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RESEARCH ARTICLE

Relationship between the Environmental Performance and the Socio-Economic Development Countries in the MENA

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ABSTRACT

The present study aims to examine the relationship between the Environmental Sustainability Index and various socio-economic indicators in MENA countries from 1990 to 2020. Using the ADF and PP tests for stationarity, Johansen for cointegration, and Granger for causality, this study aims to test the nature of the long-term relationship between the Environmental Sustainability Index and socio-economic indicators. For this reason, the VECM model has been applied. The results show that several socio-economic variables have significant coefficients, influencing environmental quality. Additionally, the long-term results reveal several unidirectional causal relationships, notably between population density, urbanization and GDP on one hand, and CO2 emissions on the other. The present study emphasizes that global and national policymakers and international development organizations must take effective measures to maintain environmental sustainability. Otherwise, global economies will not be able to achieve the path of sustainable economic development in the future. The study offers conclusive policy suggestions to maintain environmental sustainability, economic development, human development, social development, and sustainable development in MENA region economies.

1. INTRODUCTION

Meeting the needs of current and future generations is a fundamental pillar of sustainable development. Addressing present needs is not only a basic right but also a necessity for fair, equitable, and sustainable progress. However, preserving the ability of future generations to meet their own needs is both a moral imperative and a collective responsibility. This dual requirement lies at the heart of the concept of sustainability, which underscores the importance of maintaining the integrity of natural resources essential for the survival and well-being of humanity. Therefore, ensuring the sustainability of these resources constitutes a major challenge, not only for promoting economic growth but also for advancing human development (HD) and social development (SD) by fully integrating the dimensions of sustainable development (**Streimikiene,2015;Kapur, 2016; Jamel and Derbali, 2016**).

Sustainable development is a multidimensional concept that encompasses economic, social, and environmental aspects, aiming to achieve a global balance that ensures individual and collective well-being. Among traditional development indicators, the gross domestic product (GDP) occupies a central place.

GDP is commonly used as a key, universally accepted indicator for evaluating a country's economic growth (**Maity and Chatterjee, 2012**). It represents the total economic value of all goods and services produced within an economy over a given period (**Maity and Chatterjee, 2012; Daga et al., 2004; Twesige and Mbabazize, 2013**). However, while GDP is an essential tool for measuring economic performance, its limitations become evident when assessing human well-being, particularly in environmental terms. GDP primarily focuses on the quantitative aspects of development, often overlooking quality of life and environmental sustainability—two essential elements for truly sustainable development.

In this context, it is crucial to note that environmental degradation has profound implications for environmental sustainability and, consequently, for human well-being (**Duasa and Afroz, 2013**). This degradation is driven by factors such as water pollution, depletion of natural resources, greenhouse gas emissions (GHG), increased construction of nuclear power plants, industrial pollution, carbon dioxide emissions, foreign direct investment (FDI), and resource revenues. All these factors, linked to social development and economic activities, increase the demand for energy, putting greater pressure on natural resources and threatening their availability for future generations. It is therefore essential to integrate environmental sustainability as a key component in discussions on sustainable development. Preserving these resources is critical not only to meet today's needs but also to ensure that future generations will be able to meet theirs.

In this regard, environmental sustainability has taken on an increasingly important role in scientific literature, highlighting its importance in protecting natural resources and maintaining a healthy environment for current and future generations (**Kapur, 2016; Streimikiene, 2015; Jamel and Derbali, 2016**). Ecological researchers have frequently emphasized the close relationship between environmental sustainability and human well-being, arguing that environmental degradation can lead to negative consequences not only for ecosystems but also for the quality of life of individuals. Thus, environmental protection emerges as a sine qua non for harmonious development, where the economy, society, and environment coexist in balance.

The main objective of this paper is to examine the relationship between environmental sustainability, environmental performance, and socio-economic indicators in the case of MENA countries. Using an econometric model, this research aims to explore the complex dynamics between these variables, seeking to determine how environmental sustainability affects environmental performance and, conversely, how this performance impacts socio-economic indicators. This study raises crucial questions: ***To what extent can environmental sustainability influence environmental performance? What is the relationship between this performance and socio-economic indicators, such as GDP, ecological footprint, and social inequalities?***

More specifically, the research questions addressed in this paper are as follows:

- What socio-economic factors significantly affect environmental performance?
- What techniques can be employed to improve the quality of environmental factors and thereby enhance environmental sustainability?
- What methods can be utilized to reduce CO2 emissions from various economic activities while maintaining the quality of natural resources?

To answer these questions, two hypotheses are formulated:

H1: Environmental sustainability is independent of environmental performance;

H2: Environmental performance significantly impacts socio-economic indicators.

The methodological approach adopted in this study is structured in several steps. The first section briefly overviews the existing literature, highlighting the main theories and empirical studies on environmental sustainability and its impact on socio-economic indicators. The second section describes the methodology used to study these relationships, detailing the data and econometric models employed. The third section presents and analyzes the results obtained, comparing them with the formulated hypotheses. The last section is for conclusion and recommendations.

2. LITERATURE REVIEW

This section provides an extensive summary of earlier research evaluating the effects of several socioeconomic variables on environmental performance. It also includes an overview of previous studies that have developed various indices to evaluate environmental sustainability in different economies.

2.1 Environmental degradation and social-economic factors

The relationship between environmental degradation (ED) and various socioeconomic indices, such as GDP per capita, energy consumption, and economic growth, has been the subject of numerous studies conducted in various economies. These studies have employed a variety of empirical methodologies, using different characteristics as proxies for ED, including time series for each economy, panel data by province, cross-sectional data from multiple nations, and panel data by nation over extended periods.

CO2 emissions are a primary cause of climate change, soil erosion, droughts, groundwater depletion, heavy precipitation, and other environmental problems. Because of this, most studies employ data from multiple sources. As such, CO2 emissions are typically used in research as a stand-in for environmental degradation across national boundaries (**Hamida et al., 2012; Shahbaz et al., 2013; Baek and Pride, 2014; Kasperowicz, 2015; Streimikiene, 2015; Mazur et al., 2015; Gmidène et al., 2016**).

Studies conducted by **Ayeche et al. (2016); Grossman and Krueger (1991), Selden, TM and Song (1994),** show a negative correlation between economic growth and environmental quality. Using country panel data, **Grossman, GM and Krueger (1995)** assessed the relationship between per capita income and several environmental parameters. First, they acknowledge that the need for more natural resources for production raises CO2 emissions and degrades environmental quality. Second, environmental degradation is accelerated by the economy's structural transformation from agriculture to industry. Third, it is possible to lower emissions while ensuring a rise in GDP by contributing a portion of profits to research and the development of greener industrial techniques.

According to deduction of **Altinay and Karagol (2004)**, if the data were integrated of order one, there would be erroneous causation between the series. They found no evidence of a causal relationship between energy consumption and GDP in Turkey, demonstrating that the GDP and energy consumption series in that country were trend-stationary with a structural break, based on their analysis of the years 1950–2000. In contrast, however, using annual data from 1970 to 2003, **Karanfil (2008)** concluded that there is a cointegrating relationship between energy consumption and economic growth for Turkey over the years 1970 to 2005. However, upon considering the informal economy, he found that they do not exhibit cointegration.

Twesige and Mbabazize (2013) measured the relationship between environmental accounting, macroeconomic factors, and sustainable development. They concluded that there is an inverse relationship between sustainable development and macroeconomic variables. Furthermore, they claimed that raising GDP will help boost the economy going forward. They emphasized that emerging economies must preserve the sustainability of natural resources to achieve sustainable development.

Based on a literature survey, **Awan (2013)** discussed the relationship between sustainable economic development and the environment. While emerging economies deplete natural resources to support their current populations and contend with large populations, developed economies use natural resources to manufacture additional goods and services for financial gain through exports.

Numerous indicators have been established by the scientific research community and international development organizations to investigate Environmental Performance (EP) in different economies. The primary indicators currently available in studies include the Environmental Performance Index (EPI), the Sustainable Development Index, the Environmental Quality Index (EQI), the Green Life Index, the Sustainability Index Dashboard, the Living Planet Index, the Pro-Environmental Consumption Index, and the Green Competitiveness Index (**Samimi et al., 2011; Dash, 2011; Mukherjee and Chakraborty, 2013; Duasa and Afroz, 2013; Gallego-Álvarez et al., 2014; Streimikiene, 2015; Lee et al, 2017**). The research community must create a trustworthy and widely accepted indicator to quantify Environmental Performance (EP) since these indices are not supported by all scholars.

One important tool for getting national and international policymakers to take proactive measures in support of sustainable development is the Environmental Sustainability Index (ESI) (**Dash, 2011**). Furthermore, it evaluates the place of sustainable development within an economy. Nevertheless, no precise metric for evaluating an estimated index's "good, better, or worse" performance has been put out by the research community (**Dash, 2011**). Using econometric models, **Samimi et al. (2011)** investigated the relationship between the Human Development Index (HDI) and the Environmental Performance Index (EPI) in various economies. They used statistics on GDP per capita, HDI, EPI, and governance as a nation panel. They found a statistically significant and positive correlation between HDI and CAI, indicating the critical role HDI plays in environmental factor preservation. Additionally, they emphasized the correlation between higher HDI and improved access to civil registration, rights and policies, health and education services, and civil liberties. However, they did not find that HDI and CAI had a comparable effect in established and developing economies. As a result, the study was unable to offer proof regarding the impact of a high HDI on environmental performance (EP).

Using empirical ordinary least squares models, **Duasa and Afroz (2013)** evaluated how economic development maintained Environmental Performance (EP) in various economies. They took into account the Environmental Health Index (EHI) in addition to other measures, including the Ecosystem Vitality Index. In this study, the independent parameters were population density and size. They concluded that whereas population density had a negative effect on EP, economic development had a beneficial effect.

2.2 Environmental sustainability indicators

There are numerous indicators used in many studies to measure the quality or performance or degradation of the environment. Below are some of the key indicators.

- **Air quality and pollution:** Greenhouse gas (CO2) emissions are responsible for increasing environmental degradation. Consequently, air quality is a key indicator of environmental sustainability (**Selden and Song, 1994; Grossman and Krueger, 1991; Grossman and Krueger, 1995; Dash, 2011; Akbostanci et al., 2009**).
- **Good management of energy consumption:** Efficient energy management is a valuable technique for reducing the burden on natural resources. As a result, it can help reduce CO2 emissions and promote environmental sustainability (**Dash, 2011; Menyah and Wolde-Rufael, 2010a, 2010b**).
- **Ecological footprint:** The ecological footprint is an accounting tool that measures the burden imposed on nature by a given population. It shows the surface area of land required to produce the consumption of resources and the production of waste by this population. The ecological footprint, therefore, measures the pressure a human population imposes on its natural environment. It represents the land area required to support the current levels of resource consumption and waste production of this population. The originality of the ecological footprint lies in its ability to define the capacity limit of a human population.
- **Demographic pressures on ecosystem services:** A high population requires more natural resources such as arable land, irrigated land, pasture, air, forests, and water. Consequently, this leads to a significant reduction in ecosystem services (*Duasa and Afroz, 2013; Selden and Song, 1994; Akbostanci et al., 2009; Dash, 2011; Magigi, 2013; Alam, 2012; Apergis and Payne, 2014*).
- **Human health:** A clean environment is essential for human health (*Streimikiene, 2015*). It also reflects the efforts of governments and individuals to reduce the negative impact of environmental degradation on human health and natural resources (*Duasa and Afroz, 2013; Grossman and Krueger, 1995; Dash, 2011*).

3. METHODOLOGY

The main purpose of this study was to analyze the relationship between the environmental sustainability index selected for our research and various socio-economic indicators across the

MENA's economies. Selecting these economies presented a complex challenge. We verified the availability of the required data multiple times for most economies, but it was not always possible to determine the availability of data for every economy globally. To address these challenges, relevant variables were first identified based on a thorough review of related studies. These variables were then grouped. Consequently, only 10 economies had the necessary data, which were used to estimate the environmental sustainability index by country. This study utilized country-specific panel data from 10 MENA economies over a period of 31 years, from 1990 to 2020. The economies included in this study are Algeria, Bahrain, Egypt, Kuwait, Mauritania, Morocco, Qatar, Saudi Arabia, Tunisia, and the United Arab Emirates.

Data for this study were provided by the World Bank, the Global Footprint Network, the United Nations Development Program, and the United Nations Framework Convention on Climate Change. The comparison between the Environmental Sustainability Index (ESI) and socio-economic indicators was conducted using a Microsoft Excel spreadsheet, while the proposed regression models were run using EVIEWS statistical software.

In this study, the dependent variable is the environmental sustainability index, represented by CO2 emissions. The independent variables include indicators that measure environmental, economic, and social development, such as: CO2 emissions (per capita, in metric tons), ecological footprint, renewable energy consumption (% of total energy consumption), gross domestic product (GDP, per capita), foreign direct investment (FDI, % of GDP), natural resource rents (NR, % of GDP), unemployment rate, urbanization, population density, and the human development index. Except for the ecological footprint, which is sourced from the Global Footprint Network (2022), the remaining indicators are from the World Bank (2022).

To test our research hypotheses, we used a multiple regression model on panel data with an initial sample size of 3100 observations. The following table presents the description of the variables.

Table 1: Descriptive variables

Blocks	Proxy variables	Types	Unit
Environmental Sustainability Index	- CO2 emissions	Dependent variable	-Metric tons per capita
Economic indexes	- GDP - Foreign direct investment - Renewable energy consumption - Natural Resource rents	Independent variables	-PPP[1] current international - % of GDP -TOE/capita - % of GDP
Social indexes	- Human development index - Population density - Urbanization - Unemployment rate	Independent variables	-Number -People per square Km of land area -% of total -% of workers in the total labor

Source: Authors

4. ECONOMETRIC MODEL

Human development (HD), economic development (ED), social development (SD), and demographic considerations are all integral to sustainable development (**Basarir and Arman, 2014**). Since human development is a key factor in sustaining both economic development and environmental development, CO2 emissions are used in this study as a proxy for environmental quality. It is also assumed that the environmental sustainability index is functionally related to human development and economic development (**Basarir and Arman, 2014**). The environment is negatively affected by demographic factors such as rapid population growth, urbanization, and population density (**Bilsborrow, 1992; Zhang and Lin, 2012; Jafari et al., 2012; Alam, 2012; Ye et al., 2013; Stewart, 2014; Kumar et al., 2015b; Kapur, 2016; Ayeche et al., 2016; Jamel and Derbali, 2016; Kumar**

[1] PPP: Purchasing Power Parity.

et al., 2017; Sharma and Singh,). The relationship between the environmental sustainability index and the explanatory variables is expressed as follows:

$$CO2 = \alpha_0+\alpha_1(HDI)\kappa_t+\alpha_2(URB)\kappa_t+\alpha_3(DP)\kappa_t+\alpha_4(TC)\kappa_t+\alpha_5(GDP/capita)\kappa_t+\alpha_6(REC)\kappa_t+\alpha_7(NRR)\kappa_t+\alpha_8(IDE)\kappa_t+\mu\kappa_t$$

Where **HDI** is the Human Development Index, **URB** represents urbanization, **DP** is population density, **TC** denotes the unemployment rate, **GDP/capita** refers to GDP per capita, **REC** is renewable energy consumption, **FDI** stands for foreign direct investment, **NRR** indicates natural resource rents and **CO2** represents CO2 emissions. **κ** is the cross-sectional variable, and **t** denotes the time, from 1990 to 2020. α_0 is the constant coefficient, α_1 to α_5 are the regression coefficients associated with the corresponding variables, and $\mu\kappa_t$ is the error term.

5. RESULTS AND DISCUSSION

Before starting our regression analysis, it is essential to examine the characteristics of all the variables used. This includes calculating the mean, median, maximum (Max), minimum (Min), standard deviation (Std. Dev.), skewness to measure the degree of asymmetry in the distribution, kurtosis to assess whether the data are heavy-tailed or light-tailed relative to a normal distribution, and the Jarque-Bera test to evaluate the normality of the distribution by combining the skewness and kurtosis. The results are reported in the following table.

Table 2: Descriptive statistics

	CO2	HDI	URB	DP	TC	GDP	CER	RRN	FDI
Mean	13.09	0.77	71.91	187.95	7.61	15470.67	7.45	19.80	2.52
Median	4.01	0.74	73.73	65.65	7.85	5610.73	0.17	17.48	1.45
Max	47.65	0.91	100.00	1908.29	31.84	98041.36	47.00	58.92	33.57
Min	0.46	0.54	38.09	1.95	0.10	629.78	0.00	0.19	-10.95
Std. Dev.	12.99	0.10	19.99	393.24	6.50	19115.81	11.92	14.94	3.94
Skewness	0.73	-0.71	-0.15	3.05	1.02	1.83	1.86	0.58	3.46
Kurtosis	2.40	2.69	1.69	11.42	4.20	6.56	5.78	2.43	22.74
Jarque-Bera	31.91	27.03	23.38	1393.28	72.55	335.47	278.18	21.71	5633.73
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	309	309	309	309	309	309	309	309	309

Source: Authors

The descriptive statistics for the variables used in the regression model reveal some important insights. The average CO2 emissions (the dependent variable) are 13.09, with a moderate positive skewness of 0.73, indicating that the distribution is slightly right-tailed. The kurtosis of 2.40 suggests that the distribution is flatter than a normal distribution, and the Jarque-Bera test confirms non-normality with a probability of 0.00.

For the explanatory variables, the mean of the Human Development Index (HDI) is 0.77, with a skewness of -0.71, indicating a moderate left skew. The kurtosis is 2.69, slightly below 3, suggesting a mildly peaked distribution, and the Jarque-Bera test again indicates non-normality (probability of 0.00). Urbanization (URB) shows a high mean of 71.91%, with a skewness of -0.15, reflecting near symmetry in the distribution. However, the kurtosis of 1.69 suggests a flatter-than-normal distribution, and the Jarque-Bera test confirms that the distribution is not normal (probability of 0.00).

These results indicate that while some variables exhibit slight deviations from symmetry, none of them follow a normal distribution, which has implications for the choice of econometric techniques used in the analysis.

The figure 1 draws the residuals, actual values, and adjusted values of the dependent variable. It shows that the residuals are randomly distributed, indicating the absence of heteroscedasticity in our model. This underlines the robustness of the model and its relevance to the observed data.

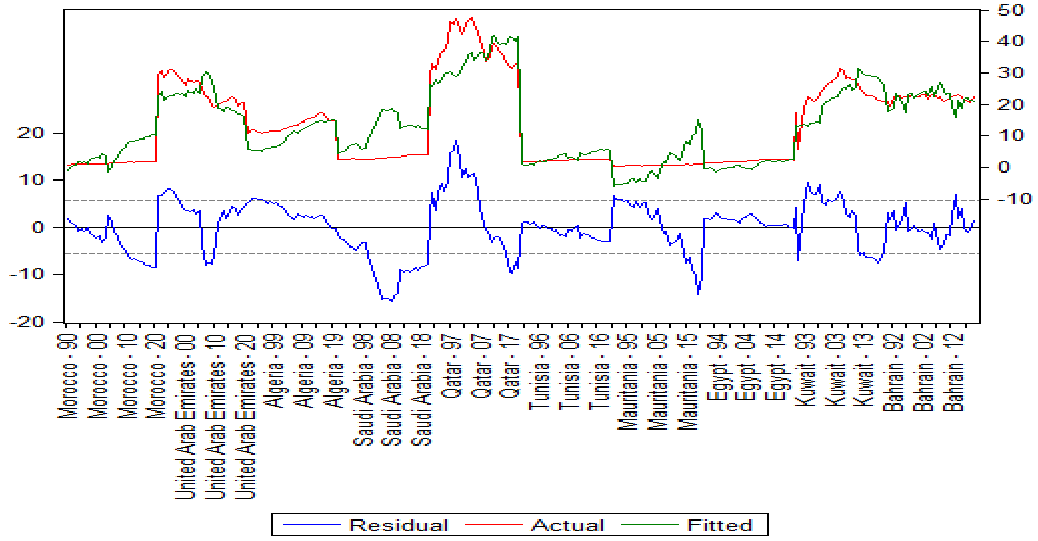

Figure 1: Scatter plot of residuals, actual values, and adjusted values of the dependent variable

Source: Authors

The figure 2 presents test the normality assumption. It shows low value of the probability associated with the Jarque-Bera statistic, which is practically zero, indicates that the residuals do not follow a normal distribution. These results suggest potential problems with the model or non-included variables that could influence the residuals, casting doubt on the reliability of the model.

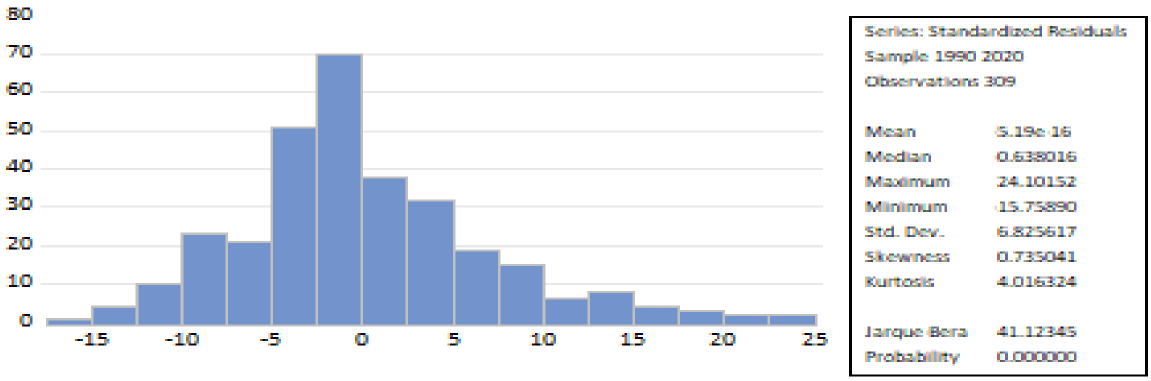

Figure 2: Normality test

Source: Authors

Table 3 presents a correlation matrix that provides an overview of the linear relationships among the various variables studied.

Table 3: Correlation matrix

	CO2	**HDI**	**URB**	**DP**	**TC**	**GDP**	**CER**	**RRN**	**FDI**
CO2	1	0.650	0.792	0.276	-0.635	0.752	-0.571	0.528	-0.055
HDI		1	0.817	0.335	-0.602	0.614	-0.883	0.539	-0.122
URB			1	0.329	-0.706	0.713	-0.697	0.673	-0.082
DP				1	-0.368	0.143	-0.244	-0.006	0.187
TC					1	-0.624	0.353	-0.501	-0.064
GDP						1	-0.447	0.497	-0.066
CER							1	-0.499	0.173
RRN								1	-0.046
IDE									1

Source: Authors

The above table shows that the CO2 emissions variable demonstrates strong positive correlations with the Human Development Index (HDI) (0.650), urbanization (URB) (0.792), and GDP per capita (0.752). This indicates that higher levels of human development, urbanization, and economic output are associated with increased CO2 emissions. Additionally, CO2 emissions show a moderate positive correlation with natural resource rent (NRR) (0.528), suggesting that economies with a greater reliance on natural resources tend to have higher CO2 emissions. On the other hand, CO2 emissions are moderately negatively correlated with the unemployment rate (TC) (-0.635), implying that higher unemployment may be associated with lower CO2 emissions.

The Human Development Index (HDI) itself is positively correlated with urbanization (0.817), GDP per capita (0.614), and natural resource rent (NRR) (0.539), indicating that as human development increases, there is a corresponding rise in urbanization, economic activity, and dependence on natural resources. However, HDI is strongly negatively correlated with renewable energy consumption (REC) (-0.883), which suggests that countries with higher human development levels tend to consume less renewable energy, possibly due to a greater reliance on fossil fuels.

Urbanization (URB) also shows strong positive correlations with CO2 emissions (0.792), HDI (0.817), and GDP per capita (0.713). This reflects the close link between urbanization, economic growth, and development. Urbanization is negatively correlated with renewable energy consumption (REC) (-0.697), similar to HDI, indicating that more urbanized regions might depend more on non-renewable energy sources.

Other variables such as population density (DP), unemployment rate (TC), GDP per capita, and natural resource rent (NRR) also display significant correlations with the other variables, providing valuable insights into the complex interconnections among the factors influencing CO2 emissions and development.

In addition, the stationarity test is used as an important step in our regression model. So, the following table reports the results of all variables according to Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) tests.

Table 4: Stationarity tests

Variables	**ADF**			**Phillips Perron (PP)**		
	Level	**First difference**	Conclusion	**Level**	**First difference**	Conclusion
REC	0.4925	0.0000	I (1)	0.5003	0.0000	I (1)
DP	0.7050	0.0000	I (1)	0.6827	0.0145	I (1)
CO2	0.2158	0.0000	I (1)	0.2062	0.0000	I (1)
FDI	0.2001	0.0000	I (1)	0.1902	0.0000	I (1)
HDI	0.2596	0.0000	I (1)	0.2442	0.0000	I (1)
GDP	0.1523	0.0000	I (1)	0.1176	0.0000	I (1)
NRR	0.1139	0.0000	I (1)	0.1051	0.0000	I (1)
UR	0.0743	0.0000	I (1)	0.0626	0.0000	I (1)
URB	0.1831	0.0000	I (1)	0.1700	0.0000	I (1)

Source: Authors

According to the Augmented Dickey Fuller (ADF) and Phillips Perron (PP) stationarity tests, we find stationarity in the first differentiation of all variables, consequently, we have reason to believe that there is cointegration between these variables.

Next, we will examine the cointegration between the corresponding variables using the Johansen test. However, it is essential to first determine the maximum number of lags to be taken into account before performing this test.

Table 5: Optimum number of delays

Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	-9856.606	NA	1.00e+21	73.89967	74.02059	73.94824
1	-4754.933	9821.198	46679.18	36.29163	37.50082	36.77735
2	-4355.243	742.4953	4297.187*	33.90444*	36.20189*	34.82731*

3	-4276.737	140.5465*	4399.270	33.92312	37.30884	35.28314
4	-4223.516	91.69188	5466.877	34.13120	38.60519	35.92837

Source: Authors

(*) Indicates lag order selected by the criterion

According to the results in Table 5, the FPE, AIC, SC and HQ criteria all recommended 2 as the optimum number of delays to be taken into account. The LR criterion, on the other hand, recommended 3 delays. We have decided to retain the first choice.

Table 6: Johansen cointegration test

Hypothesized		**Trace**	**0.05**	
No. of CE(s)	**Eigenvalue**	**Statistic**	**Critical Value**	**Prob.***
None *	0.275477	230.4443	197.3709	0.0004
At most 1	0.160678	141.1833	159.5297	0.3176
At most 2	0.114523	92.66359	125.6154	0.8097
At most 3	0.078854	58.97253	95.75366	0.9613
At most 4	0.068538	36.22068	69.81889	0.9851
At most 5	0.034885	16.55360	47.85613	0.9993
At most 6	0.022912	6.717840	29.79707	0.9995
At most 7	0.000715	0.297452	15.49471	1.0000
At most 8	0.000358	0.099189	3.841466	0.7528

Source: Authors

Note: Trace test indicates 1 cointegrating eqn(s) at the 0.05 levelJohansen's cointegration test is applied to check whether there is a cointegrating relationship between the variables in the study. Table 6 shows the presence of a single cointegrating relationship. Consequently, the use of the VECM model is justified.

In order to verify the validity of the results of the estimated VECM model, it is essential to carry out several tests on the errors, notably those relating to autocorrelation and homoscedasticity. The results of these tests are presented in tables 7 and 8, where we observe that there is no autocorrelation of the errors (the p-value is 0.8326, exceeding the 5% threshold, showing acceptance of the null hypothesis of non-autocorrelation of the errors), while the hypothesis of homoscedasticity of the errors is also accepted at the 5% threshold (p-value = 0.0600).

Table 7: Residual autocorrelation test

Lags	**LM-Stat**	**Prob**
1	190.9920	0.0000
2	99.70976	0.0776
3	68.73098	0.8326

Source: Authors

Table 8: Error homoscedasticity test

Chi-sq	**df**	**Prob.**
10006.96	8010	0.0600

Source: Authors

Table 9: Long-term and short-term results

Long-term results			
Variable	**Coefficient**	**St.Error**	**t-stat**
REC	0.041	0.671	0.062
DP	0.002	0.015	0.145
FDI	11.600	1.135	10.218

HDI	144.787	105.220	1.376
GDP	0.000	0.000	0.756
NRR	-0.071	0.308	-0.232
UR	1.769	0.858	2.059
URB	0.050	0.378	0.141
Short-term results			
Variable	**Coefficient**	**St.Error**	**t-stat**
CREC-1	-0.008	0.071	-0.116
CREC-2	0.023	0.698	0.341
DP t-1	-0.003	0.008	-0.435
DP t-2	0.004	0.008	0.501
FDI t-1	0.022	0.021	1.043
FDI t-2	0.028	0.018	1.570
HDI t-1	14.390	32.908	0.437
HDI t-2	-18.046	32.862	-0.549
GDP t-1	1.850	1.700	1.081
GDP t-2	-2.390	1.700	-1. 370
NRR t-1	0.013	0.013	1.066
NRR t-2	-0.001	0.011	-0.169
UR t-1	-0.012	0.663	-0.193
UR t-2	-0.021	0.066	-0.324
URB t-1	-0.427	0.650	-0.656
URB t-2	0.641	0.639	1.001
R2	0.812		

Source: Authors

Applying the estimated VECM model, we performed various long- and short-term Granger causality tests between the variables under consideration. Table 9 summarizes the results of these Granger causality tests. From this table, we can see the following results:

1. **For the long term**

In summary, the results suggest that the unemployment rate (UR) and FDI, have significant impacts on CO_2 emissions in the long term, while other variables present limited or non-statistically significant influences:

Foreign Direct Investment (FDI) has a significant and positive impact on CO_2 emissions, underlining the challenge of reconciling economic growth with environmental objectives.

Energy consumption seems to have a limited impact on CO_2 emissions, as does population density.

The Human Development Index (HDI) has a moderate and variable influence on CO_2 emissions, suggesting a complex relationship between human progress and environmental impact.

2. **For the short term**

The immediate effects of changes in energy consumption and population density on CO_2 emissions are significant but small, indicating some short-term instability.

FDI has a significant and positive immediate impact on CO_2 emissions in the short term, underlining a rapid response to fluctuations in foreign investment.

Changes in HDI and GDP show significant immediate effects, but with some variability, suggesting complex dynamics in the relationship between human development, economic growth and CO_2 emissions.

Overall, the dynamic equation in our study fits the data quite well, with a high R^2 (81%), meaning that the model explains around 81% of the variability in CO_2 emissions. The closer the R-squared is to 1, the better the model explains the observed variations.

Table 10: Granger causality test

Null Hypothesis	Obs	F-Statistic	Prob
PD does not Granger Cause CO2		4.90779	0.0080
CO2 does not Granger Cause PD	287	3.93520	0.0206
GDP does not Granger Cause CO2		8.27395	0.0003
CO2 does not Granger Cause GDP	287	9.05856	0.0002
URB does not Granger Cause CO2		3.73353	0.0251
CO2 does not Granger Cause URB	287	0.75314	0.4718
HDI does not Granger Cause CO2		0.26547	0.7670
CO2 does not Granger Cause HDI	287	0.16934	0.8443
NRR does not Granger Cause CO2		2.75416	0.0654
CO2 does not Granger Cause NRR	287	1.03847	0.3553
UR does not Granger Cause CO2		1.05082	0.3510
CO2 does not Granger Cause UR	287	1.17937	0.3090
FDI does not Granger Cause CO2		0.47348	0.6233
CO2 does not Granger Cause FDI	287	0.67164	0.5117
REC does not Granger Cause CO2		0.82890	0.4376
CO2 does not Granger Cause REC	287	0.03385	0.9667

Source: Authors

Table 10 shows that the Granger causality test is accepted for the following **unidirectional** relationships: Population density (PD) causes CO2 emissions, GDP causes CO2 emissions and urbanization (URB) causes CO2, and **bidirectional** relationships are found for Renewable energy consumption (REC) does not cause CO2, HDI does not cause CO2, NRR does not cause CO2, unemployment rate (UR) does not cause CO2 and Foreign direct investment (FDI) does not cause CO2.

The model's long-term estimate shows that PD, URB and GDP have a positive effect on CO2 emissions.

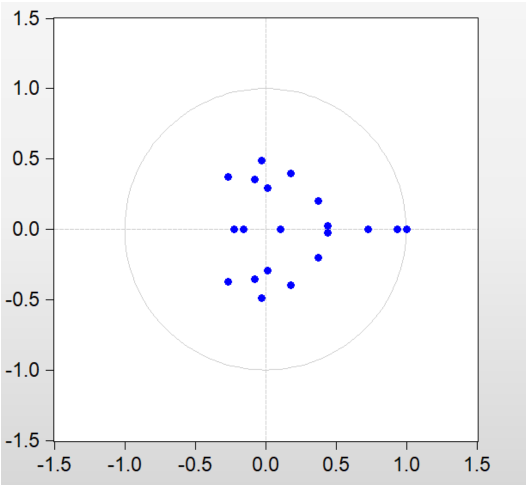

Figure 4: Inverse roots of the AR (autoregressive) characteristic polynomial

Source: Authors

The inverse roots of the AR characteristic polynomial are used to assess the stability, stationarity and order of the autoregressive model for each equation in the time series system. Figure 4 shows that all the inverse roots of the AR characteristic polynomial lie inside the unit circle, indicating that the system is stationary.

The econometric model presented in this study aims to examine the impact of social and economic development, presenting some indicators that can explain the level of development of 10 countries, on environmental performance, presenting CO2 emissions as the dependent variable, using indicators that can measure economic, human development, and social development. Therefore, the results show, generally, that economic and social development contributes positively to the environment quality as presented in the following table.

6. CONCLUSION

The main objective of this study was to investigate the causality between the environmental sustainability index with socio-economic indicators in MENA countries with time series data during the period 1990-2020.

The ADF and PP, Johansen and Granger tests were used to verify stationarity, cointegration and causality. The various causalities were examined using the (VECM) methodology.

The results of the VECM model offer interesting insights into the relationship between environmental quality and socio-economic indicators, both in the short and long term.

In the long-term results, we observe that several socio-economic variables have significant coefficients, suggesting an influence on environmental quality. Notably, the Human Development Index (HDI) shows significant and positive coefficients, underlining a positive relationship with environmental quality. This reinforces the idea that human prosperity and environmental health are closely linked, and underlines the importance of policies that promote balanced, global development. Long-term results show that:

- ✓ Unidirectional long-term causality between population density and CO2 emissions
- ✓ Unidirectional long-term causality between urbanization and CO2 emissions
- ✓ Unidirectional long-term causality between GDP and CO2 emissions
- ✓ Bidirectional causality between FDI and CO2 emissions
- ✓ Bidirectional causality between HDI and CO2 emissions
- ✓ Bidirectional causality between resource rents and CO2
- ✓ Bidirectional causality between the unemployment rate and CO2
- ✓ Bidirectional causality between Renewable energy consumption and CO2

We can conclude that, among economic indicators, GDP is the one that has a significant impact on environmental quality, establishing a causal relationship with CO2 emissions. In other words, GDP has a positive influence on CO2 emissions.

As for social indicators, there is a causal relationship between population density and urbanization on the one hand, and CO2 emissions on the other. Indeed, population density and degree of urbanization have a positive effect on CO2 emissions.

This study links environmental quality to economic and social development. It is essential to promote infrastructure development that paves the way for more jobs without diminishing the productivity of natural resources. Human development was positively linked to environmental quality, and could be improved by implementing more effective educational policies. Educational programs should incorporate environmental lessons to increase environmental awareness among the population, thus ensuring the preservation of ecosystem services in the future (Selden and Song, 1994). It is also essential to organize seminars, conferences and workshops at research universities to increase the attraction of the young population to environmental development Thus, people will have an in-depth idea to prevent the exploitation and degradation of natural resources (Saifullah et al., 2017).

It would be beneficial to set up appropriate training courses to raise people's awareness of environmental protection. In addition, increasing women's participation in the labor market and economic activities is essential to improving national income and human development.

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