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The Impact of Financial Development, Urbanization and Renewable Energy Consumption on CO2 Emissions in MENA Countries

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ABSTRACT

This study aims to explore the influence of financial development, urbanization, and renewable energy consumption on CO2 emissions in MENA countries over 2011 to 2023 by fixed effects regression model. The results of this study indicate that the financial development is positively related to carbon emissions by financing investments in the carbon intensive industries, while renewable energy compensate fossil fuels in energy mix and reduce emissions. Contrary to the urbanization exhibits a negative effect on emissions, indicating that better urban infrastructure and energy efficiency are related to lower carbon outputs. Foreign direct investments also mitigate emissions by the insertion of modern-day technologies, and higher economic complexity (expressed through trade openness and gross fixed capital formation) are associated with greater number of emissions due to industrial activity. Because otherwise, it said MENA countries would need to support so-called sustainable urbanization; greater investments in renewable energy and financial development must be realigned with environmental goals to strike a balance between economic growth and climate mitigation.

1 Introduction

In the world, carbon emissions are one of the biggest problems with devastating impacts on environmental features and economy as well as public life (Kabir et al. 2023). The buildup of CO2 in the atmosphere due to the use of fossil fuels for power generation, through our transport systems and industries, has led directly to rapid global warming, brought on by heat waves, wildfires, flood events and an increase in sea level (Salem et al. 2021; Kayani et al. 2023). These changes will pose substantial threats to both ecosystems and human populations, meaning avoiding substantial increases in greenhouse gasses is a key objective of international agreements such as the Paris Agreement. Although the issue is relevant worldwide, it poses unique challenges to the MENA region, where huge stocks of oil have long supported economic growth. With both large producers and exporters of oil and natural gas, MENA is among the biggest CO2 emitters globally; this problem is compounded by fast urban growth along within recent decade's rapid expansion through economic growth (Namdar et al., 2021). This has made the area among the most carbon rich on earth, requiring important actions to establish sustainability methods that balance financial improvement with environmental responsibility.

MENA's countries shift to renewables will lead to substantial cuts in carbon, a significant departure from the more traditional reliance on fossil fuels (Mukhtarov et al., 2022). From behind the headlines, we know that countries such as UAE, Saudi Arabia and Morocco have been making waves with an array of commercial-scale solar and wind initiatives, reducing their reliance on still abundant supplies of oil and natural gas while respecting their global climate commitments in the Paris Agreement. While financial, technological and infrastructural barriers remain, the vast solar resource of the region makes it an attractive option to continue driving down emissions (Adebayo et al., 2022). As renewable energy embeds deeper within the energy mix, it encourages economic diversification, creating jobs and improving on energy security, effectively giving MENA a stronger role to play in the global journey towards more sustainable future in terms of power.

Urbanization in MENA countries can have a strong influence on carbon emissions as the cities grow fast and promote energy use, transportation demand, and infrastructure development James (2024). An increase in urbanisation; reliance of fossil fuels and personal vehicles to move around in the city contributes to stashing up carbon emissions, whilst the continuous construction boom adds weight to the carbon footprint (Wang et al., 2018; Sun & Huang 2020; Sofuoğlu et al., 2023). At the same time, urbanization also creates an opportunity for sustainability in terms of promoting energy-efficient buildings, better public transportation services and including renewable energies into the local power size. This in turn makes the net carbon emission impact of urbanization dependent on the degree to which sustainable practices are deployed, across the MENA region. In the absence of strong policy measures and investments in green infrastructure, urbanization will further increase carbon emissions within the region (Shahbaz et al. 2016; Khan & Su, 2021; Wang et al., 2021; James, 2024).

In the MENA region, financial development is likely to play an important role in carbon emissions due to its impact on energy investments and economic growth (Rajpurohit & Sharma, 2021; Kayani et al., 2023). Financial markets and institutions provide the investments that back energy infrastructure, a major driver of global economic development but also source of emissions if this infrastructure is built based on fossil fuels. But it also provides investors with broader access to green finance that is so vital for financing renewable energy and energy efficiency. Its impact relies on robust regulatory frameworks and the financial sector realigns itself with responsible investment solutions (Dogan & Seker 2016; Khan & Ozturk 2021). The MENA countries show some progress in green finance and the tightening of environmental standards, although gaps in regulations, as well as the embryonic nature of sustainable financial practices, affect the region's ability to reduce emissions. However, if the MENA region is to optimize this positive impact it will require a framework that emphasizes green finance and strict environmental regulations that direct the financial environment in a strategic direction toward sustainability (Zaidi et al., 2019; Acheampong et al., 2020; Khezri et al., 2021).

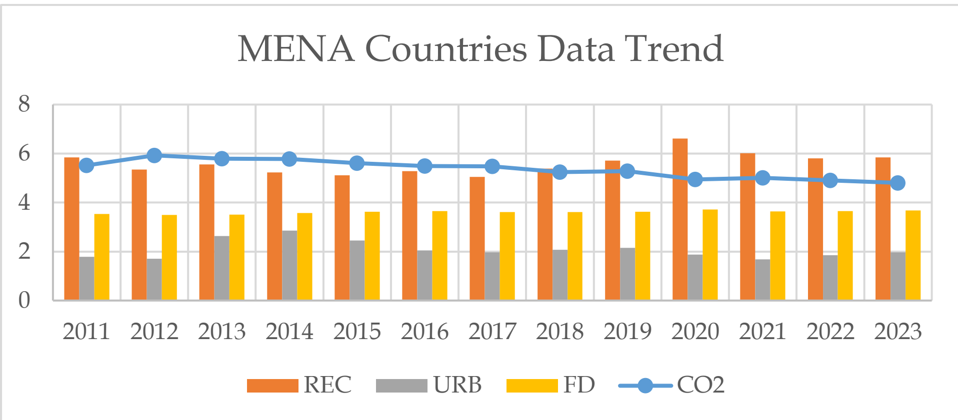

Figure 1
MENA Countries Data Trend

Figure 1 present the trends of Renewable Energy Consumption (REC), Urbanization (URB), Financial Development (FD) and CO2 emissions in MENA countries from 2011 to 2023. The REC, the orange bars that were consistently hitting around 5 units in 2011 then seemed to bust up and down a bit (a maximum of about just above 6 units in 2020 and now falling to just below 6) from there through 2023. It means different projects to use renewable energy have been ongoing through the years, and that there were some notable peaks around 2020.

The gray bars represent urbanization with an onset at about 3 units in 2011, growing mildly to somewhere around 4 units by 2014 and then maintaining steady at around between 3.5 and 4 units through to 2023. This shows a modest and consistent evolution of urbanization in the MENA region. The yellow bars (FD) begin at around 4 units in 2011 and stay almost constant with not much variation year after, more or less going around the 4-unit baseline and ending up close to the same level by the end of 2023 as well. This consistency implies that despite all the talk about growth in the financial sector, much of what has been accomplished during this period probably would have happened anyway.

The CO2 emissions, as depicted with the blue line, reached a maximum around 6.5 units in 2014 and stagnated at that level for several years until experiencing a slight downward trend after 2018, attaining levels of approximately five units by the end of our forecast in 2023. The decrease of CO2 emissions point to policies that attempt to reduce environmental impacts and incentives for a more sustainable energy mix as an increasingly relevant part in the expenditure on infrastructure.

In conclusion, the data demonstrates a clear disparity in financial development, urban growth and environmental sustainability across the MENA region. While the trends in reducing CO_2 emissions signal a positive development, the stagnation in economic growth and volatility in renewable energy consumption highlight challenges as well as opportunities, to make changes happen towards an economically stable and environmentally sustainable economy.

Problem Statement

The Middle East and North Africa (MENA) region is in a particularly tricky position, as it must balance economic growth with the need to avoid catastrophic climate change. Long a consumer of fossil fuels, the region has been an important element in global CO2 mass blooms, and with continued urbanization (which is as bad for Environmental) and growth of the financial sectors that support them, gasoline hits are just getting more difficult to keep upstream. Renewable energy is a viable solution, though the transition is complex and varies with varying dimensions of financial development, urbanization patterns, and existing energy infrastructure. Developing strategies to reduce emissions without sacrificing economic growth requires understanding how all of these elements interact, and the impact they have on carbon emission, in able for the MENA region to meet its sustainability goals and support global climate change efforts.

Objective

To access the impact of urbanization, renewable energy consumption and financial development on carbon emission in MENA countries.

Paper is organized in five sections. Section 1, 2, and 3 are allocated for introduction, literature review, and methodology. Subsequent sections present results and discussion and conclusion and policy recommendations.

2 Literature Review

Renewable Energy Consumption and Carbon Emission

Mukhtarov et al. (2023) analyzed the effect of renewable energy consumption, GDP per capita, exports and imports on CO2 emission in Azerbaijan for 1993–2019 employing Dynamic Ordinary Least Square (DOLS) methods. The outcomes of this study found the renewable energy consumption and exports reduced emissions, while GDPPC and imports positively influence emissions of CO2. Overall, the results highlighted the significance of increasing the exploitation of renewable energy as well as addressing trade dynamics to mitigate emissions. Adebayo et al. (2022) analyzed the consumption-based carbon emissions of MINT Economies, focusing on the period 1990–2018 and uncovering how renewable energy and globalization correlate with them through advanced panel econometrics. They found that carbon emission reduced with renewable energy and globalization, while they tend to increase with economic growing and non-renewable energy. The findings highlighted the need for renewable energy scaling and trade policies in these fast-growing economies to alleviate environmental stress.

Salem et al. (2021) employed the PMG approach to check out the effects of renewables on emissions for the top ten worst acidifiers mega-polluter countries over were from 1991–2018. Renewable energy, especially wind and solar, has at first an inverted U-shaped curve: it leads to more emissions as infrastructure is built, but less in the long run. Lower emissions were associated with greater forest area and technology but higher GDP, indicating the importance of integrating energy policies based on a mix of public subsidies and market mechanisms. Hasnisah et al. (2019) examined the nexus between economic development, renewable and non-renewable energy utilization and environmental degradation among thirteen developing Asian nations over 1980 to 2014 by employing panel's cointegration approach, FMOLS & DOLS approaches. Finally, the hypothesis of EKC was validated among economic growth and environmental quality deterioration through conventional energy consumption level. Although there are some shortcomings in the phenomenon of renewable energy consumption that does not reflect a reduction in CO2 emissions so that this is still with ideal conditions drafting strategic scenarios encouraging environmentally friendly and more balanced in terms of economic and environmental applicability.

Shafiei and Salim (2014) analyzed the effects of renewable and non-renewable energy on CO2 emissions in OECD for the period 1980-2011 via implementation and estimation of a STIRPAT model. Majority of CO2 emissions are increased along with the utilization of non-renewable energy and reduced by utilization of renewable energy in this study. Moreover, the estimations validated the hypothesis of EKC, evidencing that with increasing levels of urbanization, CO2 emissions stabilize or decrease. The findings indicate that clean energy and urban planning should be the main priority of policymakers in order to combat climate change.

Urbanization and Carbon Emission

Sofuoğlu et al. 2023 applied the ARDL bounds testing procedure to investigate the effect of urbanization on environmental quality in Turkey spanning from 1970 to 2020. Applying ARDL model, study has proven long run cointegrating relationship between urbanization and economic growth (ECG), energy consumption (ENRGY) and CO2 emission from fuel combustion hereafter higher urbanisation leads more in term of environmental degradation (through emissions). In this respect, Bera et al. (2023) illustrated the catalyst effects of urbanization on environmental sustainability being both a booster and bane to urban growth in their extensive review study. According to the review, urbanization powers economic growth and societal development while at the same time it aggravates environmental issues including greenhouse gas emissions, urban heat islands, biodiversity loss and pollution.

Musah, et al. (2021) studied the nexus between urbanization and carbon emissions in West Africa. The research revealed urbanization played a role in significantly increasing CO2 emissions across all panels, with the exception of renewable energy consumption, which contributed slightly to decelerate CO2 emissions. Khan and Su (2021) examined carbon emission channels through which urbanization affects newly industrialized countries (NIC), excluding member-NIC of the Organization for Economic Cooperation and Development, based on a threshold panel regression model. Urban expansion leads to net increase in carbon emissions until a certain level of urbanization threshold and then it results into reduced carbon emissions, was indicated by the findings. This showed that the right approaches to urban levels of the economic state can have a direct effect on emissions; and it emphasized energy policies should be aimed at sustainable cities in solutions to lower carbon emission.

Wang et al. (2021) studied the effects of urbanization on carbon emissions in high-income countries of OECD through a dynamic panel ARDL model. Results of this study demonstrated the emissions reduce of carbon by urbanization. Our results also indicated that urbanization and carbon emissions decoupled with the node of agglomeration effect on energy efficiency and resource consumption intensity increasing. Sun and Huang (2020) used a stochastic frontier model with data from 30 provinces over the period of 2000–2016 to examine the impacts of urbanization on carbon emission efficiency in China. Urbanization had a marked effect on how the cities used carbon in and an inverted U-shaped relationship with increasing urbanization result in decreasing carbon efficiency. Furthermore, the research indicated some differentiated urbanization strategies to increase carbon efficiency.

Abdallh and Abugamos (2017) studied the effects of urbanization on CO2 emission, by testing for an EKC hypothesis. They observed that in MENA region, CO2 emission per capita was on a decline with urbanization perpetuation process. Moreover, the findings indicate that energy consumption and economic development widely influence the carbon emissions of the area. Behera & Dash (2017) have tested the relationship of urbanization, energy consumption, FDI on CO2 emissions in South Asian countries with the dataset range 1980–2012. Urbanization, energy consumption, especially fossil fuel use are the main drivers of CO2 emissions and more tangible in middle-income countries than in high- or low-income countries.

Wang et al. (2017) examined the relationship between urbanisation, economic development, use of energy, and CO2 emissions in a sample of countries from various economic status regimes using panel data from 1980 to 2011. The outcomes revealed that there is a positive and long-run significant association between them where urbanization, energy consumption are key players inducing high levels in the CO2 emission especially for poor economies. Similarly, Shahbaz et al. (2016) examined the nonlinear correlation between urbanisation and CO2 emissions in Malaysia, revealing an inverted U-shaped environmentally the Kuznets curve. The major sources are economic growth, energy consumption and trade openness. Research showed that there is no comprehensive idea on how to deal with the urbanization as well as trade and energy use-based emissions together indicating a policy gap at global level, which, in turn press for regionally targeted research and sustainable measures.

Wang et al. (2016) examined the impacts of urbanisation on carbon emissions in the BRICS nations from 1985 to 2014 using the panel unit root technique, cointegration test, and Granger causality. The results confirmed cointegrating relationships between urbanization and carbon emissions, suggesting that the causality runs from urbanization to the CB in BRICS countries. Similarly, Li and Lin (2015) investigated the impact of urbanisation and industrialisation on energy consumption and CO2 emissions across income levels. And they discovered that while urbanization led to lower energy use, it actually increased emissions in low-income countries and raised both energy use and emissions in higher-income ones. Industrialization brought the energy consumption down in higher and middle-income groups, but raised a new set of emissions from other paths which puts across the necessity of stage-specific strategies to save energy and reduce emissions. In a study conducted by Al-Mulali et al. (2013) they investigated the nexus between urbanization, energy consumption and CO2 emissions in MENA region across 1980 to 2009. Commonly for high-income countries, significant unidirectional long-term relationships were found from all seven regions with respect to urbanization affecting energy use and emissions predominantly.

Financial Development and Carbon Emission

With respect to the association of financial development with carbon emissions, Kayani et al. (2023) indicated that an increase in most types of financial activities increases energy consumption and thereby carbon emission. While offering a measure of promise, the research also pointed to potential green technologies along with policy changes, such as carbon taxes, that could help reduce those impacts but concluded that more research is needed on which policies would be most effective and important international cooperation in achieving growth that can be sustained. Khan and Ozturk (2021) explored the direct as well as indirect impacts of financial development on CO2 emissions in 88 developing countries during the periods of 2000–2014 applying difference GMM and system GMM respectively. They showed that financial development not only reduces emissions, supporting the EKC hypothesis but also it alleviates the adverse impacts of income, trade openness and FDI on pollution. Thus, financial development might be the key to enhance environmental quality by ameliorating credit allocation and encouraging investments in clean energy projects.

Khezri et al. (2021) studied spillover effects of financial development on CO2 emissions in 31 countries of Asia–Pacific regions over the period from 2000 to 2018 by applying spatial econometric models. Financial development stimulates CO 2 emissions and energy efficiency, while statically significant spatial neighboring effects will promote fuel efficiency in the countries concerned. These findings are likely to be important for regional cooperation in both financial and environmental policies, as they indicate that even though the net effect of financial development is to increase emissions at home, it can contribute positively to environmental quality in nearby regions through spillovers. Rajpurohit and Sharma (2020) assessed the effect of economic development, along with financial development on carbon emissions in five Asian economies being India, Pakistan, Bangladesh, Sri Lanka, and Malaysia from 1980 till 2014 employing pooled mean group approach. The results confirmed the Environmental Kuznets Curve, which means that moderate economic and financial growth enhanced emissions whereas exponential growth decreased emissions finally. A direct relationship was also identified with higher emission due to high energy consumption; FDI decreased the emission on their own but increased when combined with domestic financial growth. The research advised using experienced financial sectors to neutralize environmental side-effects.

Acheampong et al. (2020) investigated the effect played by financial market development on carbon emission intensity covering 83 countries within a time span of 1980 to 2015. For emerging economies, they demonstrated that strengthening financial development lowers carbon emissions while it poses it on the other hand for frontier economies observed- indicating that their environmental policy should be geared to the level of rigs of financial development. The study of Zaidi et al. (2019) had investigated the dynamic linkages between globalization, growth in financial development and carbon emissions in APEC countries for the period 1990-2016, which employed the Wester Lund cointegration technique with CUP-BC and CUP-FM methods. Results indicate that economic growth and energy intensity will increases carbon emissions, whereas globalization and financial development decreases carbon emissions, supporting Environmental Kuznets Curve (EKC) hypothesis. The results underlined the importance of globalisation and financial sector development for environmental quality and suggested that there is a need for specific policies to regulate the externalities produced by economic growth on the environment.

3 Theoretically Framework

The relationship among CO2 emissions, urbanization, renewable energy consumption and financial development is interrelated and could be established through theories including the Environmental Kuznets Curve (EKC) and the Porter Hypothesis. The EKC theory, based on environment Kuznets curve pattern as economic development and urbanization proceeds environmental degradation such as CO2 emission rises originally with the increment of energy consumption, industrial activities and extension of transportation. CO2 emissions are also higher in urban areas, as these are centers of economic growth and need more energy, usually coming from non-renewable sources like fossil fuels. Yet, if urbanization continues on its current path, cities could drive emissions down—through the adoption of green technologies and higher efficiency standards, through more stringent environmental regulations. It is the financial sector that can further enforce this transition by ensuring access to capital for renewable energy investments and boosting R&D & sustainable practices. Using more renewable energy (e.g., wind, solar, and hydropower) reduces reliance on fossil fuels directly cuts the release of CO2 in the atmosphere. Financial markets are central to the mobilization of capital for clean energy projects, lifting investment in climate innovation and driving corporates towards reducing their carbon emissions. This reinforces the critical role of strong economies and transformation in energy to renewable, not just growth that destroy environment, for high quality urban infrastructure and environmental governance that can happen simultaneously with urbanization.

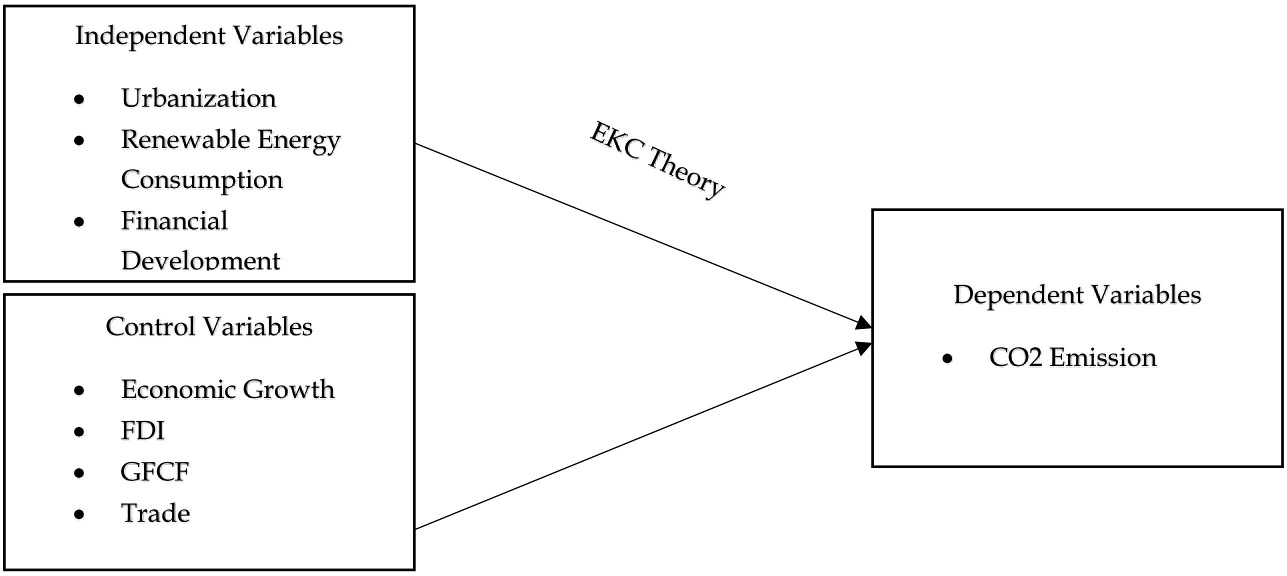

Figure 2
Conceptual Framework

4 Methodology

The study covers the data from 2011-2023 for the MENA countries. The data for this research is sourced world development indicators databank. The study used fixed effect for regression analysis. Carbon emission used as dependent variable and domestic credit to private sector (% of GDP) as proxy of financial development, GDP growth (annual %) as proxy of economic growth, urban population (% of total population) as proxy of urbanization, gross fixed capital formation (% of GDP), foreign direct investment, net inflows (% of GDP), trade (% of GDP) are used as independent variables in this study.

The simple linear model is as follows

$Y_{it} = \alpha_0 + \beta X_{it} + \varepsilon_{it}$

x and y are used as dependent and independent variables, and (t) shows time. t=1, 2, 3, ...T.

Panel data may be estimated using either a random or a fixed method. In order to evaluate the panel data, this method is useful. The idea of fixed effect is used to examine the impact of variables that change with time. Each set's constant in this model is distinct. Set methods are often called LS Dummy Variables. Within each category, this model accommodates a range of constants. The fixed impact model equation becomes:

$Y_{it} = \beta_o + \beta_1 X_{1it} + \beta_2 X_{2it} + \ldots\ldots. + \beta_k X_{kit} + \varepsilon_{it}$

The independent and dependent variables, denoted by Y_{it} and X_k, with subscripts i and t, while, β_k coefficient, ε_{it} is the error term are shown.

To check validity, F-test applied,

$H_o=0$

$H_1\neq0$

To reject the null hypothesis, the statistical F-value must be smaller than the crucial F-value.

For the second round of panel data analysis, we have the random effect technique. Each part is randomly affected by the variation.

$\beta_0 = \beta + \upsilon_i$

The standard random variable is denoted by $\upsilon_i= 0$.

The following equations describe the random effect method:

$Y_{it} = (\beta + \upsilon_{i)} + \beta_1 X_{1it}+\beta_2 X_{2it} +......+\beta_k X_{kit} + \varepsilon_{it}$

$Y_{it} = \beta + \beta_1 X_{1it} + \beta_2 X_{2it} +.....+ \beta_k X_{kit} + (\upsilon_i + \varepsilon_{it})$

Fixed effect models work better with panel datasets that include up-to-date cross-sectional data. Compared to the random effect solution, it simplifies the analysis of cross-sectional data from several survey investigations.

In 1976, Hausman devised this test based on the no correlation assumption. The Hausman test is used to determine if a random or fixed effect technique is present.

Model Specification

CO2 = f (FD, REC, URB, EG, FDI, GFCF, TRADE)

The econometric model as follows:

$CO2_{it} = \beta_o+\beta_1 FD_{it} + \beta_2 REC_{it}+ \beta_3 URB_{it} + \beta_4 EG_{it} + \beta_5 FDI_{it} + \beta_6 GFCF_{it} + \beta_7 TRADE_{it} +\varepsilon_{it}$

Where

CO2=Carbon emission

FD=Financial development

REC=Renewable energy consumption

URB=Urbanization

EG=Economic growth

FDI =Foreign Direct Investment, Net Inflows

GFCF=Gross fixed capital formation

TRADE=Trade Openness (exports + imports)

4 Results and Discussion

4.1 Descriptive Statistics and Correlation Matrix

The descriptive statistics and correlation matrix are shown in Table 1. This Table 1 shows that the average values of CO2 emissions, FD, REC, URB, EG, FDI, GFCF, and TRADE are 1.329, 3.817, 0.744, 4.316, 25.167, 0.898, 3.002, and 4.456, respectively. The maximum values of these variables are 3.104, 4.827, 3.544, 4.553, 27.734, 4.394, 3.770, and 5.852, while the minimum values are -1.172, 1.689, -4.605, 3.754, 20.876, -3.395, -0.162, and 3.396, respectively. The correlation matrix in Table 4.1 also highlights significant relationships among the key variables in our model, such as a moderate positive correlation between CO2 and EG (0.7387) and a strong negative correlation between CO2 and REC (-0.6979). These statistics are crucial in understanding the dynamics of the variables in MENA countries.

Table 1

Descriptive and Correlation Analysis

	CO2	FD	REC	URB	GDP	FDI	GFCF	TRADE
Mean	1.329	3.817	0.744	4.316	25.167	0.898	3.002	4.456
Median	1.333	4.169	1.319	4.363	25.396	0.977	3.096	4.299
Maximum	3.104	4.827	3.544	4.553	27.734	4.394	3.770	5.852
Minimum	-1.172	1.689	-4.605	3.754	20.876	-3.395	-0.162	3.396
Std. Dev.	0.993	0.706	1.990	0.214	1.615	1.088	0.477	0.642
Skewness	-0.322	-0.759	-1.090	-1.208	-0.622	-0.074	-3.161	0.788
Kurtosis	2.976	2.558	3.552	3.782	2.733	4.620	19.126	2.669
Jarque-Bera	3.127	18.829	38.135	48.626	12.195	19.945	2262.591	19.540
Probability	0.209	0.000	0.000	0.000	0.002	0.000	0.000	0.000
Sum	240.614	690.867	134.585	781.159	4555.157	162.470	543.358	806.486
Sum Sq. Dev.	177.406	89.781	712.747	8.275	469.651	213.045	40.992	74.167
Observations	181	181	181	181	181	181	181	181
Correlation Analysis								
CO2	1							
FD	0.2561	1						
REC	-0.6979	0.07392	1					
URB	0.3818	0.41502	-0.1212	1				
GDP	0.7387	0.15098	-0.6235	-0.0740	1			
FDI	-0.2666	0.19034	0.5018	0.2650	-0.5572	1		
GFCF	0.0184	-0.01623	-0.1190	0.1782	0.2111	-0.1500	1	
TRADE	-0.2305	0.17983	0.2875	0.4821	-0.6052	0.6009	0.0637	1

Unit Root Test

Table 2 presents the unit root findings for all variables using the LLC and IPS tests. The results indicate that all variables exhibit stationarity at the level. We used random and fixed effect model econometric methodologies to ascertain the long-run connection findings.

Table 2

Panel Unit Root Test

Variables	LLC				IPS				Result
	Level		1st Difference		Level		1st Difference		
	Intercept	Intercept + Trend	Intercept	Intercept + Trend	Intercept	Intercept + Trend	Intercept	Intercept + Trend	
CO2	-0.8259 (0.2044)	-4.9756 (0.0000)	-6.074 (0.000)	-5.0291 (0.0000)	0.4358 (0.6685)	-1.6532 (0.0491)	-5.3148 (0.000)	-2.5034 (0.0000)	I(O)
FD	-86.5305 (0.0000)	-82.6803 (0.0000)	-45.67 (0.000)	362.151 (1.0000)	-22.8905 (0.0000)	-31.0211 (0.0000)	-26.7363 (0.0000)	-33.7085 (0.0000)	I(O)
REC	-2.8923 (0.0019)	-4.1563 (0.0000)	-4.859 (0.000)	-4.1414 (0.0000)	-0.7846 (0.2163)	-1.2373 (0.1080)	-4.9167 (0.0000)	-2.3095 (0.0000)	I(O)

URB	-1.6082	-1.3300	-5.976	-0.9145	3.1197	2.0483	0.2404	3.0968	I(O)
	(0.0539)	(0.0918	(0.000)	(0.1802)	(0.9991)	(0.9797)	(0.5950)	(0.990)	
GDP	-3.1925	-11.8285	-12.02	-7.5922	-0.0409	-2.5929	-5.7533	-2.6540	I(O)
	(0.0007)	(0.0000)	(0.000)	(0.0000)	(0.4837)	(0.0048)	(0.0000)	(0.0040)	
GFCF	-2.7968	-5.1248	-7.638	-7.6905	-0.4172	-0.9206	-4.6506	-2.5990	I(O)
	(0.0026)	(0.0000)	(0.000)	(0.0000)	(0.3383)	(0.1786)	(0.0000)	(0.0047)	
FDI	-72.1439	-21.1841	23.573	909.458	-15.8896	-21.8086	-22.5868	-21.6660	I(O)
	(0.0000)	(0.0000)	(1.000)	(1.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	
Trade	-4.7135	-7.7479	-10.55	-11.3536	-2.6153	-2.1269	-6.5608	-4.6907	I(O)
	(0.0000)	(0.0000)	(0.000)	(0.0000)	(0.0045)	(0.0167)	(0.0000)	(0.0000)	

Hausman Test

The Hausman test ascertains the appropriate use of either the fixed-effect or random-effect methodology. The null hypothesis posits that the random-effect approach is both efficient and consistent. A high Hausman statistic leads to the rejection of the null hypothesis, suggesting that the random-effects model is unsuitable, necessitating the employment of fixed-effects estimators. If the Hausman statistic is low, the random-effects model is favoured. The test results are shown in the following table, indicating that the p-values of the random-effect model are below 5%. Hence, the fixed-effect model is applicable to determining long-term relationships.

Table 3

Hausman Test

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	48.39318	7	0.000

Fixed Effect Regression

Table 4 shows the results of fixed effect model. The first variable financial development (FD) shows a positive and significant relationship with carbon emissions, with a coefficient of 0.439. This indicates that a 1% increase in financial development leads to a 0.439% increase in CO2 emissions. This is likely because financial development facilitates access to capital, which supports investments in carbon-intensive industries, particularly in the fossil fuel sector (Acheampong et al., 2020; Rajpurohit and Sharma 2021; Kayani et al., 2023). In contrast, renewable energy consumption (REC) has a significant negative impact on emissions, with a coefficient of -0.157. A 1% increase in renewable energy consumption reduces CO2 emissions by 0.157%, underscoring the environmental benefits of cleaner energy sources, as renewable energy displaces fossil fuels in energy production (Hasnisah et al., 2019; Salem et al., 2021; Mukhtarov et al., 2022; Adebayo et al., 2022).

Urbanization (URB) also has a negative and significant impact on emissions, with a coefficient of -1.563. This result, though somewhat counterintuitive, could reflect the positive effects of improved infrastructure and energy efficiency in urban areas, leading to lower emissions, as urban centers may adopt modern technologies and more sustainable energy systems (Sofuoğlu et al., 2023Musah et al., 2021; Khan & Su 2021). Foreign direct investment (FDI) contributes to a reduction in carbon emissions, with a coefficient of -0.067, showing that an increase in FDI leads to cleaner industrial practices. This could be because foreign investments often introduce more advanced and efficient technologies, which can lower emissions in developing economies (Guoyan et al., 2022).

On the other hand, gross fixed capital formation (GFCF), with a coefficient of 0.093, and trade openness (TRADE), with a coefficient of 0.246, both contribute to higher emissions. This suggests that investments in infrastructure and greater integration into global markets are linked with increased industrial activity and energy use, thereby raising emissions, as these activities tend to rely heavily on traditional energy sources and increase transportation-related emissions (Bekhet et al., 2017). Finally, the model's overall fit is excellent, with an R-squared of 0.979, indicating that 97.9% of the variance in carbon emissions is explained by the model. This high explanatory power, combined with the significance of most predictors, points to the strong influence of financial development, trade, and investment patterns on environmental outcomes in MENA countries. However, weak environmental regulations and limited green financing options likely exacerbate the upward pressure on emissions.

Table 4

Fixed Effect Regression Results

Dependent Variable: CO2				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
FD	0.439	0.095	4.613	0.000
REC	-0.157	0.032	-4.845	0.000
URB	-1.563	0.737	-2.121	0.036
GDP	-0.099	0.079	-1.261	0.209
FDI	-0.067	0.021	-3.239	0.002
GFCF	0.093	0.039	2.386	0.018
TRADE	0.246	0.080	3.063	0.003
C	7.183	3.299	2.178	0.031
R-squared	0.979	Mean dependent var		1.334583
Adjusted R-squared	0.976	S.D. dependent var		0.993042
S.E. of regression	0.152	Akaike info criterion		-0.810884
Sum squared resid	3.668	Schwarz criterion		-0.420634
Log likelihood	94.980	Hannan-Quinn criter.		-0.652655
F-statistic	354.512	Durbin-Watson stat		0.532579
Prob(F-statistic)	0.000			

5 Conclusion & Policy Recommendation

This study analyzed the effects of urbanization, financial development and renewable energy consumption on CO2 emissions for a MENA panel of 16 counties over the period 2011-2023. The empirical analysis is conducted using fixed effect model tests. The main outcomes of this study show that urbanization and renewable energy consumption has negative impact while, financial development has positive impact on carbon emission in MENA countries.

According to this analysis, MENA countries also need to focus on promoting energy consumption renewable that can significantly reduce carbon emissions. This will require direct investments in solar, wind, and other clean energy projects as well as a mix of incentives to encourage private sector participation. We will need to better manage the inevitable urbanization through sustainable city planning, which involves energy-efficient buildings; efficient public transportation; green infrastructure for cities. More foreign direct investment, especially in green technologies, will boost emission reduction efforts even further and measures should be taken to facilitate such investments with more stability and incentives in their own policies.

All promote financial development that is aligned with environmental objectives through greening the financial systems (For examples, sustainable lending practices and green bonds). Adjust trade policies to favor low-carbon products with environmental standards, so that more trade does not mean more carbon emissions. Infrastructure should be durable in time, with energy-efficient designs and materials that support green growth. Economic policies, finally, also needs to stimulate growth that is sustainable in nature by targeting industries with low carbon footprints and ensuring expanding economic activity reinforces environment targets. In combination, these actions could allow MENA countries to move towards a truly sustainable equilibrium between economic growth and environmental protection.

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