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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.

**Keywords:** Financial Development, Urbanization, Renewable Energy Consumption, Carbon Emission, MENA Countries

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## 1. Introduction

Carbon dioxide ($CO_2$) emissions constitute a major environmental and economic challenge because their accumulation in the atmosphere contributes to climate change and affects ecosystems, public health, and economic activity (Kabir et al., 2023). Fossil-fuel combustion in electricity generation, transportation, and industry contributes to rising atmospheric $CO_2$ concentrations and associated risks, including extreme heat, wildfires, floods, and sea-level rise (Salem et al., 2021; Kayani et al., 2023). Therefore, limiting greenhouse gas emissions remains an important objective of international climate cooperation, including the Paris Agreement. Although these concerns extend across the world, the Middle East and North Africa (MENA) region faces particular challenges because oil and natural gas have historically supported economic growth. In addition, urban expansion and changing patterns of production and consumption place pressure on energy systems and environmental quality (Namdar et al., 2021). These circumstances create a need for evidence on how financial development, urbanization, and renewable energy consumption are associated with emissions while economies pursue development objectives.

The transition towards renewable energy in MENA economies presents an opportunity to reduce dependence on fossil fuels and limit carbon emissions (Mukhtarov et al., 2022). Countries such as the United Arab Emirates, Saudi Arabia, and Morocco have pursued large-scale solar and wind energy initiatives as part of broader energy diversification efforts. However, financial, technological, and infrastructure-related barriers continue to influence the pace and effectiveness of this transition. The region's substantial solar-energy potential provides an important basis for expanding renewable electricity generation (Adebayo et al., 2022). In addition, greater renewable energy consumption may support energy security, diversification, and employment, although the extent of these benefits depends on local investment conditions and policy implementation. Consequently, examining renewable energy consumption alongside financial development and urbanization is particularly relevant to the environmental challenges facing MENA countries.

Urbanization may influence carbon emissions in MENA countries by changing demand for electricity, transportation, housing, and infrastructure (James, 2024). Rapid urban expansion can increase reliance on fossil fuels, private vehicles, and construction-related energy use, thereby contributing to emissions (Wang et al., 2018; Sun & Huang, 2020; Sofuoğlu et al., 2023). However, urbanization can also facilitate energy-efficient buildings, improved public transportation, concentrated infrastructure provision, and the integration of renewable energy into urban systems. Therefore, the net association between urbanization and emissions may depend on urban planning, energy sources, and the adoption of sustainable technologies. Previous findings also suggest that the relationship can vary across economies and stages of urban development (Shahbaz et al., 2016; Khan & Su, 2021; Wang et al., 2021). For MENA economies, this variation makes the direction of the empirical association an important issue rather than a predetermined outcome.

Financial development may affect carbon emissions in the MENA region through its influence on credit availability, investment, and economic activity (Rajpurohit & Sharma, 2021; Kayani et al., 2023). Financial institutions can provide funding for productive infrastructure and industrial expansion; however, emissions may increase when these investments remain concentrated in fossil-fuel-intensive activities. Conversely, access to finance can support renewable energy projects, efficiency improvements, and environmentally preferable technologies (Dogan & Seker, 2016; Khan & Ozturk, 2021). The environmental implications of financial development are therefore not necessarily uniform. Regulatory quality, lending priorities, and the availability of green financing instruments may affect how financial resources are allocated. Similarly, existing research documents heterogeneous relationships between financial development and carbon emissions across different country groups (Zaidi et al., 2019; Acheampong et al., 2020; Khezri et al., 2021). This study therefore examines financial development alongside urbanization and renewable energy consumption in MENA countries, rather than assuming that financial expansion is inherently environmentally beneficial.

Figure 1 illustrates the reported trends in renewable energy consumption (REC), urbanization (URB), financial development (FD), and $CO_2$ emissions across MENA countries during 2011–2023. The renewable energy series, shown as orange bars, fluctuates over the observation period, peaking around 2020 before declining slightly toward 2023. These movements indicate variation in the reported renewable energy measure over time. However, the figure alone does not show whether these fluctuations resulted from specific policy interventions or individual renewable energy projects.

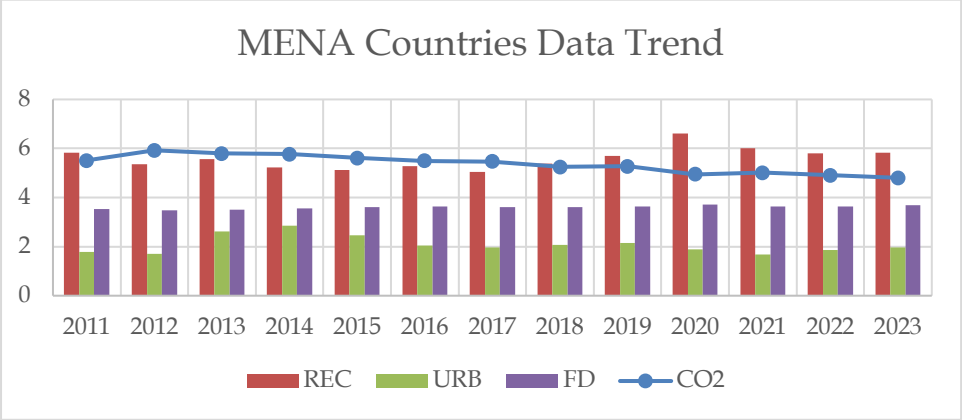



**Figure 1: MENA Countries Data Trend**

Source: Authors' presentation based on the study variables.

The grey bars represent urbanization, which increases moderately in the earlier years and then remains comparatively stable through 2023. Similarly, the yellow bars representing financial development display less pronounced variation across much of the period. These patterns suggest that the plotted measures changed at different rates. Nevertheless, limited movements in an aggregated indicator should not be interpreted as evidence that financial-sector reforms or urbanization policies had no effect. The figure is descriptive and should be considered alongside the econometric analysis and the definitions of the variables used.

The blue line representing $CO_2$ emissions remains relatively elevated in the earlier part of the period and declines gradually after approximately 2018. By 2023, the plotted emissions measure is below its earlier peak. Although this pattern is consistent with a possible improvement in the environmental indicator, the figure does not identify which economic or policy factors account for the observed decline. Therefore, the regression analysis examines associations between emissions and the selected explanatory variables.

Taken together, these descriptive trends indicate that renewable energy consumption, urbanization, financial development, and $CO_2$ emissions did not follow identical trajectories during the study period. In addition, the variation in renewable energy and the comparatively stable patterns in some other indicators provide useful context for the panel analysis. However, descriptive changes should not be treated as evidence of causality, particularly where countries differ in their economic structures and energy systems.

### 1.1. Problem Statement

The MENA region faces the policy challenge of sustaining economic development while limiting the environmental consequences of carbon-intensive activity. Historically, many economies in the region have relied substantially on fossil fuels, while continuing urbanization and financial-sector development have shaped investment and energy demand. Renewable energy provides an alternative energy source, although the transition differs across countries based on their financial resources, urban structures, and existing infrastructure. In addition, the relationship between financial development and emissions may depend on whether credit supports carbon-intensive production or cleaner technologies (Acheampong et al., 2020; Khan & Ozturk, 2021). Previous studies also report differing effects of urbanization and energy consumption on emissions (Abdallh & Abugamos, 2017; Wang et al., 2021). Therefore, examining these variables jointly in a MENA panel can clarify their empirical associations and inform policies that reconcile economic development with environmental sustainability.

### 1.2. Research Objective

To assess the associations of urbanization, renewable energy consumption, and financial development with carbon emissions in MENA countries, while accounting for economic growth, foreign direct investment, gross fixed capital formation, and trade openness.

The paper is organized into five main sections. Section 1 introduces the research problem, objectives, and regional context. Section 2 reviews the relevant literature, while Section 3 presents the theoretical framework. Section 4 explains the methodology and reports the empirical results and discussion. Section 5 provides the conclusions and policy recommendations.

## 2. Literature Review

### 2.1. Renewable Energy Consumption and Carbon Emissions

Mukhtarov et al. (2022) analyzed the effect of renewable energy consumption, GDP per capita, exports, and imports on $CO_2$ emissions in Azerbaijan for 1993–2019 employing Dynamic Ordinary Least Squares (DOLS) methods. The study found that renewable energy consumption and exports reduced emissions, while GDPPC and imports positively influenced CO2 emissions. Taken together, the results highlight the importance of increasing renewable energy use and 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 renewable energy and globalization reduce carbon emissions, while economic growth and non-renewable energy tend to increase them. The findings highlighted the need to scale up renewable energy and adjust trade policies in these fast-growing economies to alleviate environmental stress.

Salem et al. (2021) used the PMG approach to examine the effects of renewables on emissions for the top ten worst acidifier mega-polluter countries from 1991–2018. Renewable energy, especially wind and solar, initially follows 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 from 1980 to 2014 using panel cointegration, FMOLS & DOLS. Finally, the EKC hypothesis was validated between economic growth and environmental quality deterioration through conventional energy consumption levels. Although there are some shortcomings in the phenomenon of renewable energy consumption that does not reflect a reduction in $CO_2$ emissions, this is still with ideal conditions for 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 $CO_2$ emissions in OECD countries for the period 1980-2011 by implementing and estimating a STIRPAT model. In this study, $CO_2$ emissions increased with the use of non-renewable energy and decreased with the use of renewable energy. Moreover, the estimations validated the EKC hypothesis, showing that as urbanization increases, $CO_2$ emissions stabilize or decrease. The findings indicate that clean energy and urban planning should be policymakers' main priorities to combat climate change.

### 2.2. Urbanization and Carbon Emissions

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 the ARDL model, the study has proven a long-run cointegrating relationship between urbanization and economic growth (ECG), energy consumption (ENRGY), and $CO_2$ emissions from fuel combustion; hence, higher urbanization leads to more environmental degradation (through emissions). In this respect, Bera et al. (2023) illustrated the catalytic effects of urbanization on environmental sustainability as both a booster and a bane to urban growth in their extensive review study. According to the review, urbanization powers economic growth and societal development while also aggravating 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 found that urbanization significantly increased $CO_2$ emissions across all panels, except for renewable energy consumption, which slightly slowed $CO_2$ emissions. Khan and Su (2021) examined the carbon emissions channels through which urbanization affects newly industrialized countries (NICs), excluding member NICs of the Organization for Economic Cooperation and Development, using a threshold panel regression model. The findings indicate that urban expansion leads to a net increase in carbon emissions up to a certain urbanization threshold, after which it results in reduced carbon emissions. This showed that appropriate approaches to urban economic development can directly affect emissions, and it emphasized that energy policies should aim for sustainable cities as a solution to lower carbon emissions.

Wang et al. (2021) studied the effects of urbanization on carbon emissions in high-income OECD countries using a dynamic panel ARDL model. The results showed that urbanization reduces carbon emissions. Our results also indicated that urbanization and carbon emissions are 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 2000–2016 to examine the impact of urbanization on carbon emissions efficiency in China. Urbanization had a marked effect on how cities used carbon, and an inverted U-shaped relationship with increasing urbanization resulted in decreasing carbon efficiency. Furthermore, the research indicated some differentiated urbanization strategies to increase carbon efficiency.

Abdallah and Abugamos (2017) studied the effects of urbanization on $CO_2$ emissions by testing the EKC hypothesis. They observed that in the MENA region, $CO_2$ emissions per capita declined with urbanization. Moreover, the findings indicate that energy consumption and economic development strongly influence the area's carbon emissions. Behera & Dash (2017) tested the relationship between urbanization, energy consumption, and FDI and $CO_2$ emissions in South Asian countries using data from 1980–2012. Urbanization and energy consumption, especially fossil fuel use, are the main drivers of $CO_2$ emissions and are more tangible in middle-income countries than in high- or low-income countries.

Wang et al. (2018) examined the relationship between urbanization, economic development, energy use, and $CO_2$ emissions in a sample of countries across various economic status regimes, using panel data from 1980 to 2011. The results revealed a positive, long-run significant association, with urbanization and energy consumption as key drivers of high $CO_2$ emissions, especially in poorer economies. Similarly, Shahbaz et al. (2016) examined the nonlinear correlation between urbanization and $CO_2$ emissions in Malaysia, revealing an inverted U-shaped environmental Kuznets curve. The major sources are economic growth, energy consumption, and trade openness. Research showed that there is no comprehensive understanding of how to address urbanization alongside trade- and energy-use-based emissions, indicating a global policy gap and calling for regionally targeted research and sustainable measures.

Wang et al. (2016) examined the impacts of urbanization on carbon emissions in the BRICS nations from 1985 to 2014 using panel unit root tests, cointegration tests, and Granger causality. The results confirmed cointegrating relationships between urbanization and carbon emissions, suggesting that causality runs from urbanization to carbon emissions in BRICS countries. Similarly, Li and Lin (2015) investigated the impact of urbanization and industrialization on energy consumption and $CO_2$ emissions across income levels. They found that while urbanization reduced energy use, it increased emissions in low-income countries and raised both energy use and emissions in higher-income ones. Industrialization reduced energy consumption in higher- and middle-income groups but increased emissions from other sources, underscoring the need for stage-specific strategies to save energy and reduce emissions. Al-Mulali et al. (2013) investigated the nexus between urbanization, energy consumption, and $CO_2$ emissions in the MENA region from 1980 to 2009. Commonly, for high-income countries, significant unidirectional long-term relationships were found across all seven regions, with urbanization predominantly affecting energy use and emissions.

### 2.3. Financial Development and Carbon Emissions

Regarding the association between financial development and carbon emissions, Kayani et al. (2023) found that increases in most types of financial activity increase energy consumption and, therefore, carbon emissions. While offering a measure of promise, the research also pointed to potential green technologies and policy changes, such as carbon taxes, that could help reduce these impacts, but concluded that more research is needed on which policies would be most effective and on the importance of international cooperation in achieving sustainable growth. Khan and Ozturk (2021) explored the direct and indirect impacts of financial development on $CO_2$ emissions in 88 developing countries during 2000–2014, applying difference GMM and system GMM, respectively. They showed that financial development not only reduces emissions, supporting the EKC hypothesis, but also alleviates the adverse impacts of income, trade openness, and FDI on pollution. Thus, financial development may be key to improving environmental quality by improving credit allocation and encouraging investment in clean energy projects.

Khezri et al. (2021) studied the spillover effects of financial development on $CO_2$ emissions in 31 Asia–Pacific countries from 2000 to 2018 using 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 important for regional cooperation in both financial and environmental policies, as they indicate that although 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 (2021) assessed the effect of economic

development, along with financial development, on carbon emissions in five Asian economies, India, Pakistan, Bangladesh, Sri Lanka, and Malaysia, from 1980 to 2014, employing a pooled mean group approach. The results confirmed the Environmental Kuznets Curve, meaning that moderate economic and financial growth increased emissions, whereas exponential growth ultimately reduced them. A direct relationship was also identified with higher emissions due to high energy consumption; FDI decreased emissions on its 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 of financial market development on carbon emissions intensity, covering 83 countries from 1980 to 2015. For emerging economies, they demonstrated that strengthening financial development lowers carbon emissions, while for frontier economies, it has the opposite effect, indicating that their environmental policy should be geared to the level of financial development. Zaidi et al. (2019) investigated the dynamic linkages between globalization, financial development growth, and carbon emissions in APEC countries from 1990 to 2016, using the Westerlund cointegration technique with CUP-BC and CUP-FM methods. The results indicate that economic growth and energy intensity increase carbon emissions, whereas globalization and financial development decrease them, supporting the Environmental Kuznets Curve (EKC) hypothesis. The results underlined the importance of globalization and financial sector development for environmental quality and suggested the need for specific policies to regulate the environmental externalities produced by economic growth.

The literature therefore suggests that financial development can be associated with either higher or lower emissions depending on the economic and institutional setting (Acheampong et al., 2020; Khan & Ozturk, 2021; Khezri et al., 2021). Similarly, studies of urbanization report both emission-increasing and emission-reducing relationships (Abdallh & Abugamos, 2017; Khan & Su, 2021; Wang et al., 2021). Against this mixed evidence, the present study contributes a joint assessment of financial development, urbanization, and renewable energy consumption within a MENA country panel for 2011–2023. Its contribution is primarily regional and comparative rather than a new causal identification strategy.

**3. Theoretical Framework**

The proposed relationships among $CO_2$ emissions, urbanization, renewable energy consumption, and financial development can be considered in relation to the Environmental Kuznets Curve (EKC) framework and arguments about innovation and environmental regulation associated with the Porter Hypothesis. The EKC perspective suggests that environmental degradation may initially intensify with economic expansion but can subsequently decrease as technology, regulation, and production structures change (Shahbaz et al., 2016; Shafiei & Salim, 2014). Urbanization can increase the demand for energy-intensive transport, construction, and industrial activity; however, it may also generate efficiencies through infrastructure concentration, public transport, and improved technology (Khan & Su, 2021; Wang et al., 2021). Similarly, renewable energy consumption can reduce dependence on conventional fuels, while financial development can finance both carbon-intensive production and low-emission investment (Dogan & Seker, 2016; Acheampong et al., 2020). These competing channels support the study's examination of the observed direction of each association. Importantly, the present linear fixed-effects model does not directly test an EKC turning point or the Porter Hypothesis; rather, these perspectives provide conceptual context for interpreting the estimated relationships.

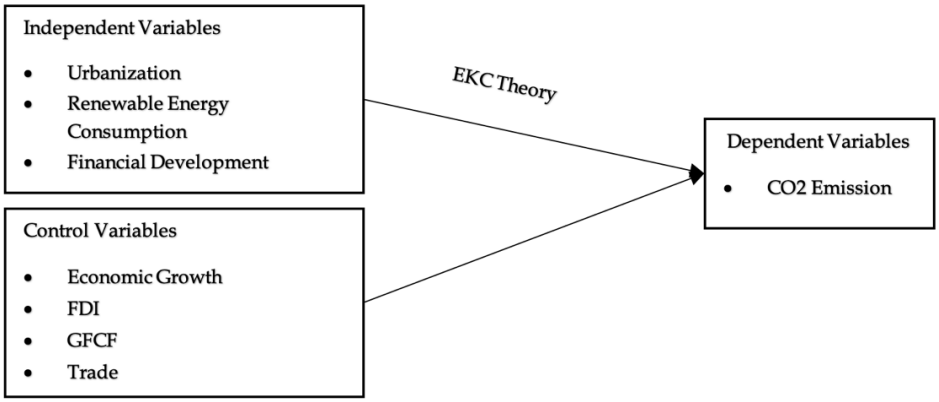



**Figure 2:** Conceptual Framework**.** Source: Developed by the authors.

**4. Methodology**

This study uses panel data for MENA countries covering 2011–2023. The data are drawn from the World Development Indicators database, and the empirical analysis applies a fixed-effects regression model. Carbon emissions serve as the dependent variable. Financial development is proxied by domestic credit to the private sector as a percentage of GDP, while urbanization is measured by the urban population as a percentage of the total population. Renewable energy consumption is also included among the principal explanatory variables. In addition, economic growth is represented by annual GDP growth, gross fixed capital formation by its share of GDP, foreign direct investment by net inflows as a percentage of GDP, and trade openness by trade as a percentage of GDP. The original dataset reports 181 observations across the included variables (Table 1). The paper describes a panel of 16 MENA countries; however, the reported sample size indicates that the panel is not fully balanced over the 13-year study period. Accordingly, data coverage and the treatment of missing observations are important when interpreting the estimates.

The simple linear model is as follows

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

In this notation, Y denotes the dependent variable, X represents the explanatory variable, i identifies the country, t identifies the year, and ε is the error term; t = 1, 2, 3, …, T.

Panel regression can be estimated using either fixed-effects or random-effects specifications. The fixed-effects approach accounts for time-invariant country-specific characteristics that may be correlated with the explanatory variables. Consequently, the coefficients are identified from variation within countries over time, conditional on the included controls. Country-specific intercepts may be represented by dummy variables in a least-squares dummy-variable formulation. The corresponding fixed-effects equation is expressed as follows:

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

Here, $Y_{it}$ is the dependent variable for country i in period t, $X_{kit}$ denotes the kth explanatory variable, $\beta_k$ is its estimated coefficient, and $\varepsilon_{it}$ is the disturbance term. The specification also allows for country-specific intercepts.

An F-test can be used to assess relevant restrictions on the model, with the precise null and alternative hypotheses depending on the specification being compared:

$H_o = 0$

$H_1 \neq 0$

Reject the null hypothesis when the calculated test statistic exceeds the relevant critical value, or equivalently when its p-value falls below the selected significance level.

The random-effects approach provides an alternative panel specification in which unobserved country-specific effects are treated as random components. Its suitability depends, among other assumptions, on the absence of correlation between the country-specific effects and the explanatory variables.

$\beta_0 = \beta + \upsilon_i$

The country-specific random component is represented by $\upsilon_i$, conventionally assumed to have an expected value of zero.

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-effects estimation is useful when unobserved, time-invariant country characteristics may be correlated with the regressors. However, this approach does not by itself address all potential sources of endogeneity, time-varying omitted factors, heteroskedasticity, or serial correlation. Consequently, interpret the results as conditional within-country associations unless additional identification assumptions and diagnostic evidence are available.

The Hausman specification test compares fixed-effects and random-effects estimators under the null hypothesis that the random-effects estimator is consistent. Rejection of the null favours the fixed-effects specification, whereas failure to reject does not establish that all other model assumptions hold.

### 4.1. Model Specification

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

The empirical model is specified 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)**

## 5. Results and Discussion

### 5.1. Descriptive Statistics and Correlation Matrix

Table 1 presents the descriptive statistics and correlation coefficients for $CO_2$ emissions, financial development (FD), renewable energy consumption (REC), urbanization (URB), the reported GDP measure, foreign direct investment (FDI), gross fixed capital formation (GFCF), and trade openness (TRADE). The corresponding reported means are 1.329, 3.817, 0.744, 4.316, 25.167, 0.898, 3.002, and 4.456. The table also documents variation in the observed ranges and dispersions. The correlation between $CO_2$ emissions and the reported GDP measure is positive (r = 0.7387), whereas the correlation between emissions and REC is negative (r = −0.6979). However, pairwise correlations do not control for the other variables or country-specific characteristics and must not be interpreted as causal effects. In addition, the negative minima for certain reported variables and the magnitude of the GDP series suggest that the precise data transformations and measurement units should be considered when interpreting the results.

**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 |

| | CO2 | FD | REC | URB | GDP | FDI | GFCF | TRADE |
|---|---|---|---|---|---|---|---|---|
| **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 |

Source: Authors' calculations based on World Development Indicators data.

### 5.2. Panel Unit Root Tests

Table 2 reports the Levin–Lin–Chu (LLC) and Im–Pesaran–Shin (IPS) panel unit root tests at levels and first differences. The reported outcomes differ across variables and across specifications with intercepts and trends. For example, several level-test p-values are above conventional significance thresholds, including certain urbanization and renewable energy specifications. Therefore, the table does not consistently support the statement that every variable is stationary at level under every specification. The integration-order classification should consequently be treated with caution. In addition, first-difference results should be distinguished from evidence of level stationarity, and the tests do not independently establish a long-run equilibrium relationship.

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

Source: Authors' calculations based on World Development Indicators data.

### 5.3. Hausman Specification Test

The Hausman test is used to evaluate whether the random-effects specification is consistent relative to fixed effects. Under the null hypothesis, the random-effects estimator is consistent and efficient under its maintained assumptions. As reported in Table 3, the chi-square statistic is 48.39318 with seven degrees of freedom and a reported p-value of 0.000. Therefore, the null is rejected at the 5% significance level, and the fixed-effects specification is preferred for the reported analysis. However, this test does not demonstrate a long-run relationship or establish the absence of other specification problems.

**Table 3:** Hausman Test

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

Source: Authors' calculations based on World Development Indicators data.

### 5.4. Fixed-Effects Regression

Table 4 reports the fixed-effects regression results. Financial development (FD) has a positive and statistically significant coefficient ($\beta = 0.439$, $p < .001$), indicating a positive conditional association with $CO_2$ emissions. This finding is consistent with the possibility that additional financial resources support emissions-intensive economic activities, although the investment channel is not directly measured in the model (Acheampong et al., 2020; Rajpurohit & Sharma, 2021; Kayani et al., 2023). In contrast, renewable energy consumption (REC) is negatively associated with emissions ($\beta = -0.157$, $p < .001$). This result aligns with evidence linking greater renewable energy use to reduced reliance on conventional energy sources (Hasnisah et al., 2019; Salem et al., 2021; Mukhtarov et al., 2022; Adebayo et al., 2022). However, the coefficients should not be described as percentage elasticities unless the transformations of the dependent and explanatory variables establish such an interpretation.

Urbanization (URB) also shows a negative and statistically significant association with $CO_2$ emissions ($\beta = -1.563$, $p = .036$). Although this direction may appear contrary to studies identifying increased emissions during urban expansion, it is compatible with research indicating that urban concentration and improved efficiency can coincide with lower emissions under certain conditions (Abdallh & Abugamos, 2017; Khan & Su, 2021; Wang et al., 2021). Nevertheless, the model does not directly measure urban infrastructure quality or energy efficiency, and these mechanisms remain possible explanations rather than established findings. Similarly, foreign direct investment (FDI) has a negative coefficient ($\beta = -0.067$, $p = .002$), which is consistent with the potential contribution of technology transfer and more efficient production practices (Guoyan et al., 2022). However, the estimate does not identify the technology composition of incoming investment or establish a causal mechanism.

Several limitations should be considered when using these estimates. First, the analysis relies on an unbalanced panel of reported country-year observations, and the study does not provide a complete country-level missing-data account. Second, the discussion of transformed values and variable measurement needs to be considered when interpreting the scale of coefficients. Third, the fixed-effects estimator does not eliminate concerns about reverse causality or omitted time-varying influences. Finally, the available reported tables do not provide a complete panel-specific assessment of serial correlation, heteroskedasticity, and cross-sectional dependence. Accordingly, robustness checks and alternative specifications are useful directions for subsequent research, but no unreported tests are claimed as having been conducted in this study.

Comparison with previous research further clarifies the significance of these findings. The positive financial-development coefficient is compatible with studies reporting that financial expansion can intensify environmental pressures, whereas other research identifies emission-reducing effects in different financial and institutional contexts (Acheampong et al., 2020; Khezri et al., 2021; Khan & Ozturk, 2021). The negative renewable energy coefficient is consistent with evidence that cleaner energy can reduce carbon emissions (Adebayo et al., 2022; Hasnisah et al., 2019). Moreover, the urbanization result resembles findings that urban concentration may be associated with reduced emissions in some settings (Abdallh & Abugamos, 2017; Wang et al., 2021), although other studies show the opposite pattern (Musah et al., 2021; Sofuoğlu et al., 2023). Therefore, the results are best understood as context-dependent empirical evidence rather than universal relationships applicable to every MENA economy.

Gross fixed capital formation (GFCF) and trade openness (TRADE) have positive and statistically significant coefficients ($\beta = 0.093$, $p = .018$; and $\beta = 0.246$, $p = .003$, respectively). These associations may reflect the energy and transportation demands accompanying investment and international trade, particularly where production remains dependent on conventional fuels (Bekhet et al., 2017; Dogan & Seker, 2016). By contrast, the reported GDP coefficient is negative but not statistically significant ($\beta = -0.099$, $p = .209$), and therefore does not provide sufficient evidence of a conditional relationship in this specification. The reported R-squared of 0.979 indicates a high degree of in-sample fit; however, such a value does not establish causal identification or rule out specification problems. In addition, the reported Durbin–Watson statistic of 0.533 raises a concern about residual serial correlation, for which a suitable panel-specific diagnostic assessment would be valuable. These findings should consequently be

understood as associations conditional on the included variables and fixed effects, rather than definitive evidence of policy effects.

**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 | | | |

Source: Authors' calculations based on World Development Indicators data.

**6. Conclusion and Policy Recommendations**

This study examined the associations of urbanization, financial development, and renewable energy consumption with $CO_2$ emissions in a panel of 16 MENA countries during 2011–2023. The empirical analysis used a fixed-effects model, including economic growth, foreign direct investment, gross fixed capital formation, and trade openness as additional regressors. The reported results indicate negative associations between urbanization and renewable energy consumption and emissions, whereas financial development shows a positive association. In addition, foreign direct investment has a negative coefficient, while gross fixed capital formation and trade openness have positive coefficients. These results contribute regional evidence on the relationships among financial activity, urban development, energy consumption, and environmental outcomes; however, the observational model does not establish causal mechanisms.

The findings support continued attention to renewable energy expansion in MENA economies, particularly through investment in solar, wind, and other low-emission technologies. Policies that encourage private investment may help address financing constraints, although their effectiveness depends on institutional capacity and energy-market conditions. Similarly, sustainable urban planning can emphasize energy-efficient buildings, reliable public transport, and greener infrastructure. The negative urbanization coefficient should nevertheless be interpreted cautiously because the model does not directly test which features of urban development explain the observed association. In addition, the negative association with FDI suggests that the environmental composition of foreign investment warrants attention, including the potential contribution of cleaner production technologies (Guoyan et al., 2022). Policy implementation should therefore account for differences among MENA economies rather than assuming a uniform regional response.

Financial development should also align more closely with environmental priorities through measures such as sustainable lending practices, transparent green-finance criteria, and well-designed green bonds (Acheampong et al., 2020; Khan & Ozturk, 2021). Moreover, trade and infrastructure policies can promote resource efficiency and lower-emission production while recognizing that trade openness and fixed capital formation are positively associated with emissions in the reported model. Public investment programmes may place greater emphasis on efficient designs, durable materials, and cleaner energy use. However, these recommendations arise from estimated associations and should be evaluated against country-specific institutional and economic circumstances. Future empirical research could examine heterogeneity between oil-exporting and oil-importing economies and investigate whether financial development moderates the relationship between renewable energy consumption and emissions. Such extensions would require additional model estimation and cannot be inferred directly from the results reported here. The present findings nevertheless offer a basis for discussing how financial policy, urban development, and energy transition strategies can support environmental objectives alongside economic development.

**Ethical Statement**: This study uses secondary country-level indicators from the World Development Indicators database and does not involve human participants or identifiable personal data. Therefore, ethical approval and individual informed consent are not applicable to the described research design.

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