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Human capital and manufacturing activities under environmentally-driven urbanization in the MENA region

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Middle East and North Africa (MENA) region possesses immense capacity for renewable energy generation. Despite the potential, most countries in the region are yet to fully embrace renewable energy. Non-renewable sources still dominate their energy mix. This study examines the interplay between urbanization, renewable and non-renewable energy consumption, and environmental quality in the six Middle Eastern and North African countries from 1990 to 2021, using the mean group (MG), the mean group dynamic least squares (DOLSMG), the common correlated effect (CCE), augmented mean group (AMG) and the cross-section augmented ARDL (CS–ARDL). Accounting for urbanization, and economic growth, the findings of DOLSMG indicate that while renewable energy and manufacturing activities significantly contribute to environmental quality, urbanization and human capital development significantly contributes to environmental degradation. The CS-ARDL short-term and long run estimation result showed that manufacturing activities significantly contribute to environmental quality, When examined by country, it was found that there is a unidirectional causal relationship from economic growth, manufacturing value added, urbanization, human capital development to dioxide emissions in Saudi Arabia. While there is a unidirectional causality from manufacturing value added to dioxide emissions in Jordan, and a unidirectional causality from urbanization to dioxide emissions in Tunisia.

KEYWORDS

renewable energy, urbanization, economic growth, manufacturing activities, CO2 emission, MENA region

1 Introduction

The Middle East and North Africa (MENA) region stands at a pivotal crossroads, where the imperative for sustainable development intersects with the potential for a renewable energy revolution (Damrah et al., 2022a; Damrah et al., 2022b; Jahanger et al., 2022; Sinha et al., 2022; Balsalobre-Lorente et al., 2023b; Satrović et al., 2023). The region's natural endowments position is an asset for renewable energy generation. This is a much needed transition considering the global urgency to mitigate climate change impacts (Doğan et al., 2022; Balsalobre-Lorente et al., 2023a; Khalil et al., 2023). Like in most countries in the global South, rate of urbanization especially in the is increasing steadily creating serious obstacles for sustainable urban development (Rana, 2011; Chen et al., 2016). Urbanization that is ecologically driven has been attributed to a number of factors, including economic liberalization, the widespread of clean technologies, and novel methods to pollution control. The impacts of urbanization on the environment have grown to be a serious worry because of the high proportion of the world's population that lives in bigger cities (Zhang et al., 2022; Bajja et al., 2023). Researchers and law-makers have acknowledged the need for sustainable urban development long-term policies to address energy related challenges especially in the era of rapid urbanization, alongside fluctuation of oil and gas production (Kabisch et al., 2022; Rasoulinezhad and Taghizadeh-Hesary, 2022). MENA, a region rich in natural gas and petroleum reserves, has experienced fluctuations in its oil and gas reserves over the years (Hafner et al., 2023). The region exhibits potential for renewable energy generation but faces significant challenges due to its heavy reliance on fossil fuels and inefficient resource allocation (Satari Yuzbashkandi et al., 2023). Despite this resource abundance, many countries in the region heavily subsidize fuel, leading to inefficient resource allocation and hindering the adoption of clean technologies. The heavy reliance on gas and oil, along with energy-intensive industrial projects, has contributed to a significant carbon footprint in the region. Addressing these issues and promoting the adoption of clean energy sources is crucial for mitigating climate change and ensuring sustainable development, especially in regions that rely heavily on fossil fuels (Guo et al., 2023). But this also requires an understanding of the relationship between urbanization, renewable energy, and environmental quality towards developing effective sustainable development and climate change policies.

In light of this, some theories have attempted to explain the environmental impacts of urbanization, such as ecological modernization, urban environmental transition (Randolph and Storper, 2023). and compact city (Kain et al., 2022). However, empirical investigations have yielded mixed results, showing both positive and negative effects of urbanization on CO2 emissions (Bidone, 2022). Some studies suggest a positive correlation between urbanization and CO2 emissions, while others find negative or statistically insignificant relationships (Apergis et al., 2023). Urbanization-pollution relationship may vary depending on the given countries, data sample, and estimation technique used in the analysis (Effiong, 2018). Until now, research on the relationship between urbanization and pollution in Africa has been limited.

Yet, the transition remains sluggish as the dominance of non-renewable energy sources persists, raising critical questions about the region's future trajectory in light of environmental sustainability. The necessity of this study arises from a pressing policy-level conundrum: how can MENA countries pivot to renewable energy while managing urbanization and human capital development to enhance environmental quality? (Snieška and Zykienė, 2014; Ghafar, 2020; Treiblmaier et al., 2020; Hu et al., 2021; Guo and Liu, 2022; Li and Pang, 2022; Pazienza et al., 2022).

This research is timely and necessary, addressing the policy-level problem of reconciling the growth of human capital and manufacturing activities with environmentally sustainable urban development in the MENA region (Liu et al., 2020; Treiblmaier et al., 2020). The persistent reliance on non-renewable energy amidst the potential for renewable alternatives highlights a significant policy gap. This study provides a lens through which to view the interactions between energy consumption patterns, the expansion of human capital, and the manufacturing sector's evolution within the urbanization process. By exploring these dynamics, it seeks to inform policies that could steer the region towards a more sustainable and resilient future (Alharthi et al., 2021; Jahanger et al., 2022; Khalil et al., 2023).

The selection of six MENA countries for this study is particularly pertinent, as they present a microcosm of the broader region's challenges and opportunities. This choice of sample not only reflects the diverse stages of urbanization and industrialization but also the varying degrees of investment in human capital development and renewable energy infrastructure. The econometric analysis through MG, DOLSMG, CCE, AMG, and CS–ARDL models provides a robust framework for understanding these complex relationships over 3 decades, encompassing different economic cycles and policy shifts (Jahanger et al., 2022; Balsalobre-Lorente et al., 2023a; Balsalobre-Lorente et al., 2023b; Balsalobre-Lorente et al., 2023c; Esmaeili et al., 2023).

Moreover, an aspect of policy and scholarly concern has been the role of human capital development in the context of environmentally driven urbanization (Jahanger et al., 2022). Human capital development, which consists of people's knowledge, education, talents, and skills, is crucial in determining urbanization tendencies and their environmental effects (Šlaus and Jacobs, 2011). In light of this, this paper examines the interplay between urbanization, renewable and non-renewable energy consumption, and environmental quality in six Middle Eastern and North African countries. It utilizes data from 49 African countries covering the period from 1990 to 2010 to conduct a more in-depth investigation into the potential relationship between urbanization and the environment. The analysis employs the STIRPAT model, which is a widely used analytical framework for assessing the driving forces behind anthropogenic environmental changes.

In addition to the STIRPAT model, the article of Baltagi and Li (2002) utilizes a semi-parametric panel fixed effects estimator to explore the urbanization-environment relationship, which is not known beforehand. This estimation technique is beneficial as it avoids biases arising from functional form misspecification and considers possible non-linearities and parameter heterogeneity. Instead of imposing a specific functional form from the start, this approach enables the data generating process to determine the true nature of the relationship between urbanization and pollution. This approach is expected to provide more accurate and nuanced insights into the complex dynamics between urbanization and environmental impacts in Africa.

Moreover, while the study is region-specific, the implications of its findings hold broader relevance. The MENA region is not unique in its struggle to balance economic development with environmental sustainability. Therefore, the insights gleaned could inform policies in other regions facing similar challenges, though with the caveat that policy applicability must consider regional specificities.

Generalizability is a nuanced prospect, hinging on the commonalities between the MENA context and other geopolitical environments (Jahanger et al., 2022; Balsalobre-Lorente et al., 2023a; Satrović et al., 2023).

The novelty of this study lies in the analysis of an existing interplay where policy interventions could most effectively foster an environmentally driven influence. By delineating the short-term benefits and long-term detriments of manufacturing activities on environmental quality, the research underscores the need for a strategic policy intervention. It advocates for an integration of renewable energy policies with urban planning and education reform to foster a sustainable nexus of human capital and manufacturing prowess (Salvucci et al., 2019; Delponte and Schenone, 2020; Feruni et al., 2020; Baer et al., 2021; Fu and Ng, 2021). This study aims to examine the interplay between urbanization, renewable and non-renewable energy consumption, and environmental quality in the six Middle Eastern and North African countries. In so doing, we draw data from 1990 to 2021, using the mean group (MG), the mean group dynamic least squares (DOLSMG), the common correlated effect (CCE), augmented mean group (AMG) and the cross-section augmented ARDL (CS–ARDL). This study is organized as follows. The next section 2 reviews the existing literature review and the hypotheses of the study. Section 3 introduces the data, materials and methods of the study. Section 4 presents and discusses the findings of the study. Finally, Section 5 concludes the paper and highlights the major policy recommendations.

2 Urbanization, renewable energy and environmental quality: a review

The pursuit of consistent economic growth and progress has led developing nations diverging from the goal of transitioning into low-carbon societies (as noted by Ali et al. (2019a)). While transition into low-carbon societies is imperative, the linkage between energy usage, environmental preservation, and economic development is of great importance and worth investigating. Effective control of these factors is crucial for the welfare of humanity, the promotion of sustainable development, and the establishment of sound policy direction (Temiz Dinç and Akdoğan, 2019). Insofar, studies abound on examining the interconnectivity of these variables and the potential effect of renewable energy (RE) on environmental sustainability (Nathaniel et al., 2020; Abbasi et al., 2022; Zhang and Umair, 2023). Previous studies have often used CO2 emissions as a proxy for environmental quality (e.g., Azizalrahman, 2019; Bekun et al., 2019; Gokmenoglu and Sadeghieh, 2019; Saint Akadiri et al., 2019), and more recently, ecological footprint (EF) has been adopted (Alola, 2019b; Hassan et al., 2019). While the use of CO2 emissions as a proxy has been criticized for not being comprehensive enough since it does not consider the individual impact on the environment. Therefore, EF has gained attention as a better proxy. Some studies analyzed the effect of both RE and non-renewable energy (non-RE) on EF and consistently found that RE consumption reduces EF, promoting environmental quality (Nathaniel et al., 2020; Rafique et al., 2022). Conversely, non-RE is associated with environmental degradation, emphasizing the need to promote and use clean energy sources for sustainable development (e.g., Bello et al., 2018; Destek et al., 2018; Ozcan et al., 2018; Baloch et al., 2019a; Destek and Okumus, 2019; Dogan et al., 2019).

In the MENA region, Saidi et al. (2018) delved into the interplay between institutional quality, renewable energy (RE), and economic growth. They determined that RE and all aspects of institutional quality foster economic growth, except for bureaucratic factors. In a similar vein, Abdouli and Hammami (2017) scrutinized the connection between non-renewable energy (non-RE) and economic growth across 17 MENA countries spanning from 1990 to 2012. Their findings reveal a positive association between energy consumption and economic growth. Charfeddine and Kahia. (2019) conducted an investigation on the impact of RE consumption on CO2 emissions within the MENA region, covering the years 1980–2015, using the panel VAR technique. Their results suggest that RE has limited influence on CO2 emissions. Within the same region, non-RE sources are significant contributor to environmental degradation (Gorus and Aslan, 2019; Yang et al., 2021) Jin and Kim (2018) explored the determinants of CO2 emissions in 30 countries during the period of 1990–2014, highlighting that nuclear energy, unlike RE, contributed to CO2 emissions. This study underscored the importance of developing RE as a means to combat global warming. Within MERCOSUR countries, Related studies have highlighted the role of RE in mitigating CO2 emissions while implicating non-RE sources as a cause of CO2 emissions (De Souza et al., 2018; Kahia et al., 2019).

In some instance, RE, exports, and financial development stimulate economic growth (Hassine and Harrathi, 2017). RE may negatively impact economic growth, while non-RE sources may positively influence economic growth (Sinha et al., 2017). This was attributed to the cost of implementing RE systems in countries heavily reliant on non-RE sources. Rasoulinezhad and Saboori (2018) provided evidence in a study involving 12 selected Commonwealth States that RE reduced CO2 emissions, with similar effects attributed to financial development. Other studies, however, found a positive relationship between CO2 emissions and financial development (Pao et al., 2011; Pao and Tsai, 2011; Al-Mulali et al., 2015; Farhani and Ozturk, 2015).

Elsewhere in Asia, RE, research and development, and trade positively contributed to growth, while the same effect was not observed for non-RE consumption (Zafar et al., 2019). However, experiences from Africa were contrast that of Asian countries. For example, Nathaniel and Iheonu (2019) study in Africa, reveal that RE had a minimal impact on CO2 reduction, RE instead, enhanced environmental quality (Riti and Shu 2016).

In Malaysia, Lau et al. (2018) economic growth and foreign direct investment (FDI) are the main drivers of RE consumption. Similar results were reported for Turkey by Temiz Dinç and Akdoğan (2019). A feedback causality between RE and growth, as well as a one-way causal relationship from non-RE consumption to economic growth were found. Others (e.g., Khoshnevis Yazdi and Ghorchi Beygi, 2018) have demonstrated how trade and RE promoted environmental quality by reducing CO2 emissions in the African context.) But in the context of China, significant correlation was found between household size, income, and energy consumption (Ali et al., 2019). In western Africa, Radoine et al. (2022) analyzed by adopting the method of DriscollKraay panel regression. The panel result suggested that manufacturing

TABLE 1 Definition and data source of variables.

Variable	Definition	Data source
Carbon emissions	CO_2 Emissions *per capita*	WDI database
Economic growth	Gross Domestic Product *per capita*	WDI database
Manufacturing value-added	Manufacturing value-added (% of total GDP)	WDI database
Urbanization rate	Urbanization rate	WDI database
Human capital investment	The HDI measures the development of a country in terms of income, education, and health	United Nations Development Program
Renewable energy	Renewable energy consumption Per capita in kWh'	EIA website 'https://www.eia.gov/'

Note: Period of the data is from 1990 to 2021.

TABLE 2 The results of VIF test.

Variable	*VIF*	*1/VIF*
LNRE	4.35	0.230134
LNGDP	3.63	0.275303
LNURB	2.92	0.342078
LNHCD	2.74	0.365626
LNMVA	1.45	0.689238
Mean VIF		3.02

value-added, urbanization, financial development, and foreign direct investment increase environmental degradation. In addition, the findings of this study revealed that economic growth and renewable energy consumption contribute, significantly, to environmental quality.

Rafei et al. (2022) study was probably one of the first studies to examine the effect of the economic complexity on ecological footprint and classify countries based on their institutional quality levels. Furthermore, the interaction of economic complexity and natural resource rents is considered as a new variable.

Furthermore, energy and environmental economics have highlighted the effects of human capital and manufacturing activities development on environmentally-driven urbanization. The connections between financial development, human capital development, and environmental deterioration have been the core of several research. The Environmental Kuznets Curve (EKC) is a major idea in this field of study. According to the EKC, environmental degradation initially rises with rising wealth *per capita* but then eventually falls. Recent studies, however, have questioned the reliability of the EKC, indicating that less developed nations are more capable of addressing environmental challenges than developed nations in terms of environmental norms (Stern, 2004).

Economic liberalization, the spread of clean technologies, and innovative methods to pollution management have all been recognized as significant impactful variables in developing nations as the driving forces behind environmentally-driven urbanization (Dasgupta et al., 2002). These elements contribute to environmental destruction and economic growth. In the context of environmentally-driven urbanization, it is also vital to take into account the connection between poverty and the deterioration of natural resources. The rural poor, who are frequently based in ecologically vulnerable regions, rely significantly on natural resources for their survival. Increased resource deterioration may result from this aforementioned dependency. Therefore, tackling poverty and giving the poor other means of subsistence is crucial factor for sustainable urbanization.

Overall, it is essential to acknowledge the importance of financial development and human capital. Thus, people's knowledge, education, abilities, and skills, is essential for advancing sustainable development and environmental preservation. The ability of people to adopt sustainable practices and technology can be improved through investments in education and training (Xepapadeas, 2005).

3 Material and methods

In this research investigation, we incorporated specific variables, which encompassed CO2 emissions, GDP growth as an indicator of economic expansion, manufacturing value-added (MVA), urbanization rate (URB), investment in human capital development (HCD), and the utilization of renewable energy (RE). Our research focused on six countries in the MENA region: Morocco, Tunisia, Egypt, Jordan, Saudi Arabia and Lebanon. For our analysis, we compiled annual data covering the period from 1990 to 2021. While our intention was to use more recent and comprehensive data, we were constrained by the availability of comprehensive and consistent CO2 emissions data, which was only available up to 2021.

The data used in this research study were obtained from the World Development Indicators (WDI) for the year 2023, which is made available by the World Bank. Information related to renewable energy was specifically extracted from the IEA (International Energy Agency) website. To calculate carbon emissions, the study uses the following equation or formula.

$$CO2 = f\,(GDP; MVA; URB; HCD; RE) \tag{1}$$

In Eq 1, the variable "CO2" represents carbon emissions measured in tonnes *per capita*. "GDP" is Gross Domestic Product *per capita*, expressed in current US dollars, and serves as a proxy for economic growth. "MVA" represents manufacturing value added as a percentage of total GDP. "URB is the urbanization rate, expressed as a percentage of the total population. "HCD" stands

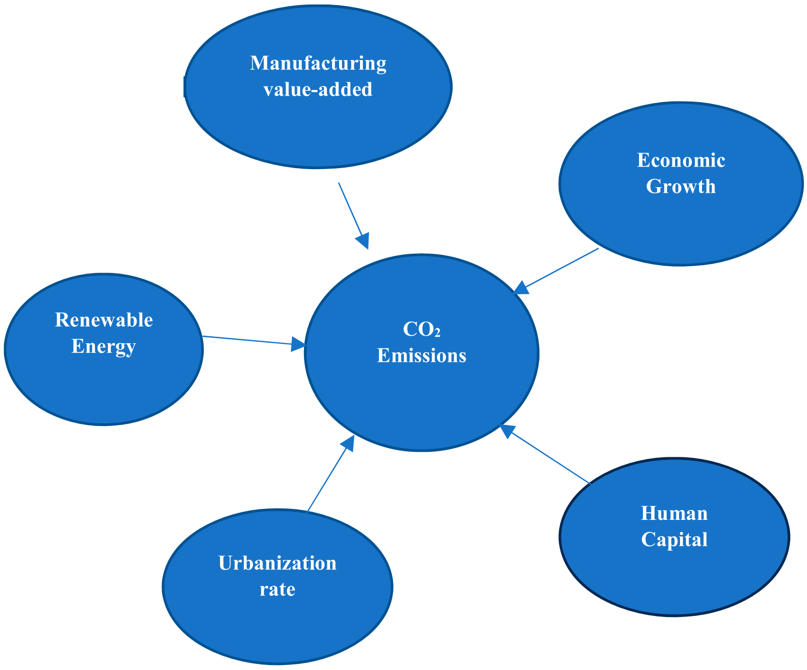

FIGURE 1
Conceptual framework. Source: authors constructed.

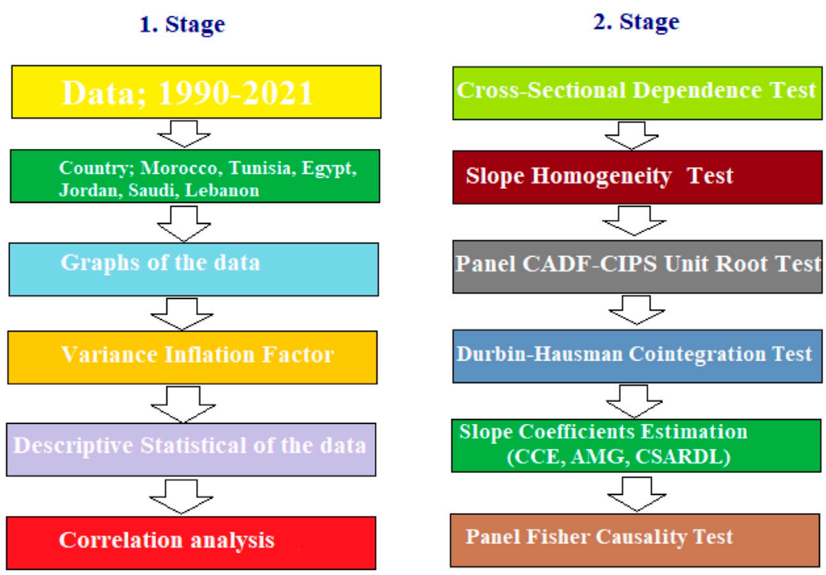

FIGURE 2
Methodological framework. Source: authors constructed.

for Human Capital Development and measures a country's development in terms of income, education and health (see Figure 1 and Table 1).

All of the variables utilized in this model are transformed into logarithmic form. This transformation is carried out to reduce the impact of extreme values in the data, ensuring a more stable and balanced analysis.

$$LCO_{it} = \beta_0 + \beta_{1t}GDP_{it} + \beta_{2t}LMVA_{it} + \beta_{3t}LURB_{it} + \beta_{4t}LHCD_{it} + \beta_{5t}LRE_{it} + \varepsilon_{it}$$

whereas i represents the number of countries; t shows the quantity of time; ε is the error term; and $\beta_1, \beta_2, \beta_3, \beta_4, and\ \beta_5$, are the coefficients of economic growth, manufacturing value-added, urbanization rate, human capital development, renewable energy use, respectively.

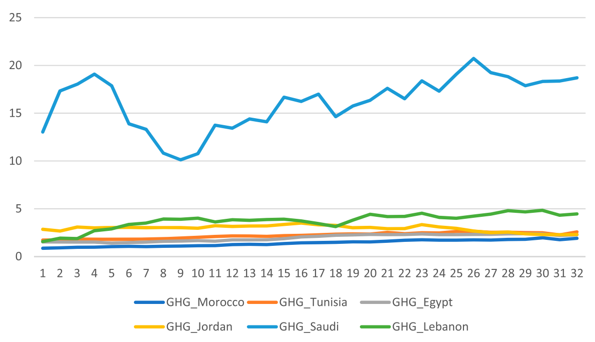

FIGURE 3
CO_2 emission levels of MENA region Countries.

4 Results and discussion

Table 2 shows the results of the VIF test for appropriate model selection (see Figure 2). Following the results, there is no multicollinearity problem in the built model and the variables used are appropriate for the model. Table 3 provides a summary of the sampled data set for the six countries over the 32-year time frame (1990–2021) of the variables defined below and represented in Figure 3–7. It can be seen that the median values of manufacturing value added, gross domestic product, CO2 emissions, urbanisation rate, human capital development and renewable energy use in the selected countries are 0.91, 4.09, 2.69, 4.27, −0.37 and 1.81 in logarithmic terms, respectively. Following the results on CO2 emissions, the maximum is 3.03 while the minimum is −0.14. Also, GDP ranges from 2.62 to 4.72 with a sample mean of 3.94. In the case of manufacturing value added, the sampled economies recorded a maximum of 3.05 and a minimum of 0.34, with an average of 2.59. Furthermore, urbanisation, recorded a maximum value of 4.52 and a minimum of 3.75 of the urban population, with an average annual rate of 4.20 of the urban population. Human capital development recorded the maximum of −0.13 and the minimum is −0.81 with an average annual rate of −0.39. While renewable energy consumption recorded the maximum of 3.14 and the minimum of −4.71 with an average annual rate of 0.96 in logarithmic terms.

For the six selected countries, Table 4 shows a negative correlation between CO2 emissions and the two indicators MVA and RE. On the other hand, CO2 emissions have a positive correlation with URB and HCD.

The countries of the MENA region are linked through their involvement in manufacturing and various sectors of the economy, which promotes cross-sectional dependence among them. Therefore, as a first step, we examined the existence of cross-sectional dependence (CD) or independence among these countries. Thus, it is essential to assess the CD issue before conducting panel data estimates for the MENA region. In this regard, Table 5; Table 6 show that the existence of cross-sectional dependence has been established for both the model and the variable for the MENA countries. Furthermore, the results of the homogeneity test in Table 7 indicate that the slope coefficients have a heterogeneous structure.

As a second step, the second-generation test (i.e., CADF test) is used for unit root testing, as opposed to the conventional unit root tests. This is crucial to study these methods of Pesaran (2007), as it can reveal the level of integration amidst CD and heterogeneity. The empirical results shown in Table 8 ensured that the variables in the MENA region panel are integrated at I (1) except for the LNURB variable, so we can check the cointegration among the variables. However, we have already found CD in our data.

Having established the different order of integration of the selected series, the third step of our empirical study was to examine the cointegration properties using the Durbin-Hausman cointegration proposed by Westerlund (2008). This cointegration test is a test that can be applied to different levels of stationarity of the series. The results of the Westerlund test, as shown in Table 9, indicate the existence of a long-run relationship between CO2 as the dependent variable and our chosen explanatory variables. This observation implies the existence of cointegration between the series. Consequently, we accept the alternative hypothesis and reject the null hypothesis of "no cointegration".

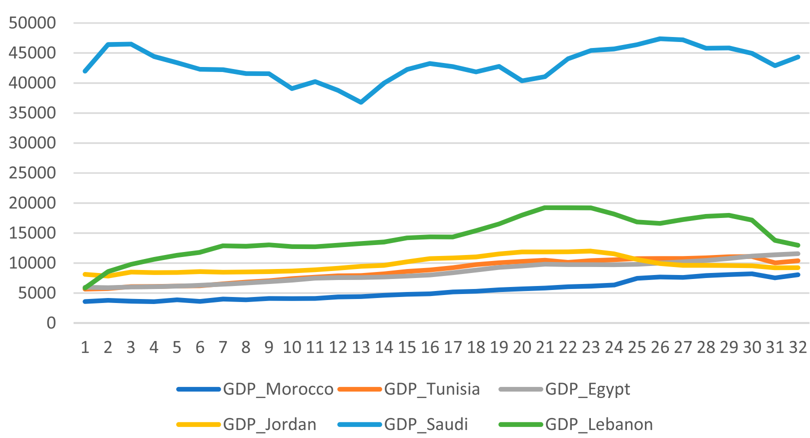

FIGURE 4
GDP levels of MENA region countries.

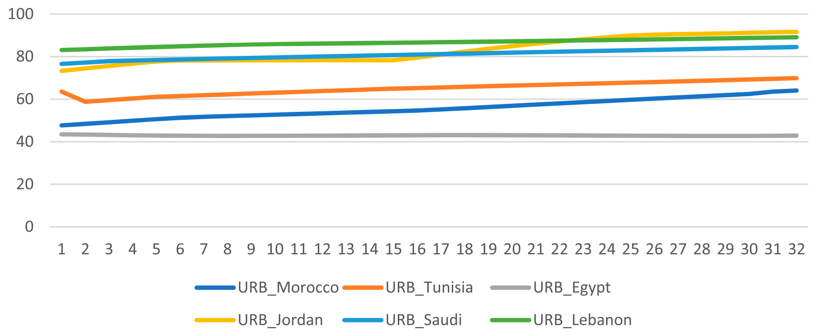

FIGURE 5
Urbanization rate levels of MENA region countries.

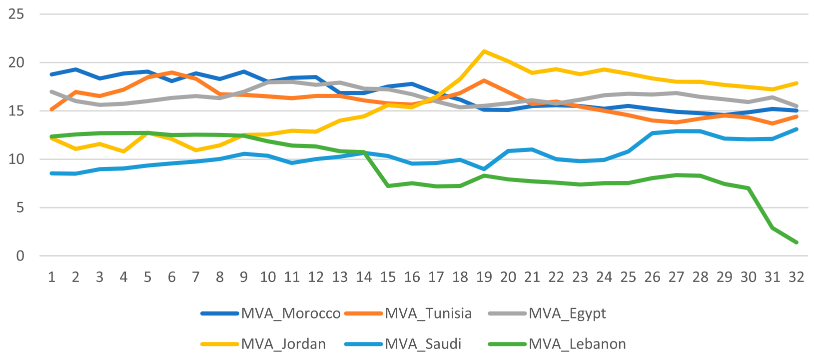

FIGURE 6
Manufacturing value-added levels of MENA region countries.

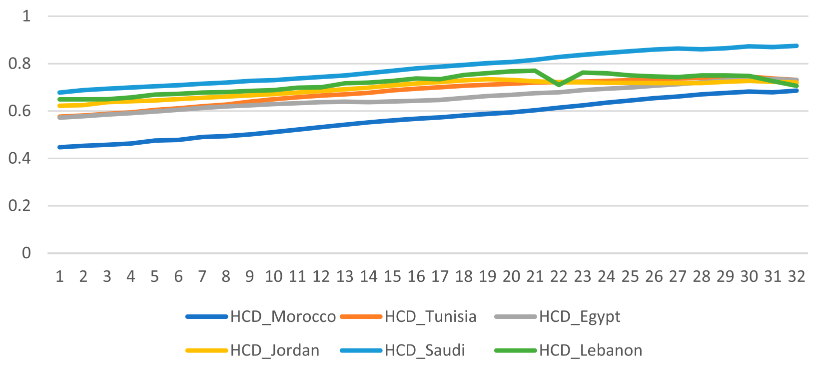

FIGURE 7
Human capital development levels of MENA region countries.

After finding cointegration among variables, we use the mean group (MG), the mean group dynamic least squares (DOLSMG) developed by Pedroni (2001), the common correlated effect (CCE) developed by Pesaran (2006), the augmented mean group (AMG) introduced by Eberhardt and Bond (2009) and Eberhardt and Teal (2010), the cross-sectional augmented ARDL (CS-ARDL) introduced by Chudik et al. (2016) estimators. MG is an effective estimator when all parameters are heterogeneous but there is no cross-sectional dependence. Our parameters are heterogeneous and there is cross-sectional dependence in our model, so MG results are not reliable. However, other estimators produce effective results in the presence of heterogeneity and cross-sectional dependence. First,

TABLE 3 Descriptive Statistics of selected variables.

	LNCO2	LNGDP	LNMVA	LNURB	LNHCD	LNRE
Mean	1.15	3.94	2.59	4.20	−0.39	0.96
Median	0.91	4.09	2.69	4.27	−0.37	1.81
Maximum	3.03	4.72	3.05	4.52	−0.13	3.14
Minimum	−0.14	2.62	0.34	3.75	−0.81	−4.71
Std. Dev	0.81	0.47	0.34	0.26	0.13	2.44
Skewness	1.07	−0.78	−2.38	−0.60	−0.87	−1.58
Kurtosis	3.19	2.75	13.87	1.96	4.26	3.89
Observations	192	192	192	192	192	192

TABLE 4 Correlation analysis results.

	LNCO2	LNGDP	LNMVA	LNURB	LNHCD	LNRE
LNCO2	1.00					

LNGDP	−0.13	1.00				
	(0.06)	-----				
LNMVA	−0.55***	−0.13	1.00			
	(0.00)	(0.06)	-----			
LNURB	0.59***	0.47***	−0.52***	1.00		
	(0.00)	(0.00)	(0.00)	-----		
LNHCD	0.76***	0.30***	−0.40***	0.58***	1.00	
	(0.00)	(0.00)	(0.00)	(0.00)	-----	
LNRE	−0.94***	0.36***	0.40***	−0.42***	−0.58***	1.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	-----

Note. Numbers in paranthess state probability values. ** and *** depict 5% and 1% significance.

TABLE 5 The results of cross-sectional dependence tests for variables.

Test	LNCO2	LNGDP	LNMVA	LNURB	LNHCD	LNRE
Breusch-Pagan LM	187.52 (0.000)	144.80 (0.000)	135.86 (0.000)	331.20 (0.000)	413.93 (0.000)	124.36 (0.000)
Pesaran scaled LM	30.40 (0.000)	22.60 (0.000)	20.97 (0.000)	56.63 (0.000)	71.74 (0.000)	18.87 (0.000)
Bias-corrected scale LM	30.70 (0.000)	22.50 (0.000)	20.87 (0.000)	56.53 (0.000)	71.64 (0.000)	18.77 (0.000)
Pesaran CD	7.57 (0.000)	7.69 (0.000)	2.64 (0.008)	10.63 (0.000)	20.30 (0.000)	2.91 (0.000)

Note: ** and *** depict 5% and 1% significance.

ceteris paribus, DOLSMG results show that a 1% increase in LNMVA reduces LNCO2 by 0.33%, conversely to the empirical results of Khan et al. (2021a) for the United States and Khan et al. (2021b) for thirty-eight IEA countries.

while a 1% increase in LNHCD increases LNCO2 by 2.25%. Another statistically significant result is that a 1% increase in LNRE reduces LNCO2 by 0.02%. These empirical results agree with the outcomes of Orhan et al. (2021) for India, Kirikkaleli and Adebayo (2021) for India, Shan et al. (2021) for highly decentralized economies, and Kirikkaleli and Adebayo (2020) for the global context. However, ceteris paribus, the CCE estimation results show that a 1% increase in LNHCD raises lnCO2 by 1.99%, while the AMG estimation results demonstrate that a 1% increase in LNHCD raises lnCO2 by 1.16%. In addition, for the AMG estimator, a 1% increase in LNRE reduces LNCO2 by 0.17%. However, the CS-ARDL method will provide unbiased

TABLE 6 The results of homogeneity test.

Test	t-ist	p-value
Δ	7.71***	0.000
adj. Δ	8.726***	0.000

Note: *** depicts 1% significance.

TABLE 7 Panel unit root test results.

Variable	Level		First difference	
	t-bar	*p*-value	t-bar	*p*-value
$LNCO_2$	−2.329	0.078	−3.439****	0.000
LNGDP	−1.715	0.567	−3.522***	0.000
LNMVA	−1.635	0.648	−3.517***	0.000
LNURB	−3.749	0.000	-	
LNHCD	−1.915	0.363	−2.508**	0.029
LNRE	−1.102	0.270	−3.969***	0.000

Note: ** and *** denote 5% and 1% significance, respectively.

TABLE 8 The results of cross-sectional dependence tests for model.

Test	Statistic	p-value
LM	27.4**	0.0257
LM adj*	5.294***	0.000
LM CD*	0.666	0.5049

Note: ** and *** depict 5% and 1% significance respectively.

TABLE 9 Cointegration test Westerlund (2008).

Panel A: Constant	Value	*p*-value
DH_g	2.389	0.240
DH_p	−1.384*	0.083
Panel B: Constant and trend		
DH_g	2.389	0.992
DH_p	−1.448*	0.074

Note: * depicts 10% significance. DH_g indicates Durbin-Hausman group statistics, while DH_p states Durbin-Hausman panel statistics.

and effective estimation results in the estimation of variables that are stationary at different degrees, as well as cross-sectional dependence and slope heterogeneity (Chudik et al., 2016). In this context, the short-term estimation results of CS-ARDL indicate that a 1% increase in LNMVA reduces LNCO2 by 0.20%, while a 1% increase in LNHCD raises LNCO2 by 2.03%. The long-term results of CS-ARDL prove that a 1% increase in LNMVA reduces LNCO2 by 0.102, while a 1% increase in LNHCD rises LNCO2 by 1.05%. The result that manufacturing activities value-added (MVA) increases environmental quality is quite interesting. It can be expected that technology-based, environment-friendly value-added production will have a positive impact on environmental quality. On the other hand, the fact that the MVA variable was used as a ratio of GDP in the data set we used may have given this result (see Table 10).

After estimating the slope coefficients, the panel Fisher causality results developed by Emirmahmutoğlu and Köse (2011), which can be used for heterogeneous panels and variables based on different levels of stationarity, are presented. When examined by country, it was found that there is a unidirectional causal relationship from LNGDP, LNMVA, LNURB, LNHCR to LNCO2 in Saudi Arabia. While there is a unidirectional causality from LNMVA to LNCO2 in Jordan, it can be said that there is a unidirectional causality from LNURB to LNCO2 in Tunisia (see Table 11).

There is also a unidirectional causality from LNRE to LNCO2 in Tunisia. In the full panel, unidirectional causality was found from LNGDP to LNCO2, from LNMVA to LNCO2, from LNURB to LNCO2, from LNHCR to LNCO2, from LNRE to LNCO2. According to the more reliable bootstrap *p*-values, there is a unidirectional causal relationship only from LNMVA and LNRE to LNCO2.

5 Conclusion and policy implications

5.1 Conclusion

The paper examines the interplay between urbanization, renewable and non-renewable energy consumption, and environmental quality in six Middle Eastern and North African countries. In so doing, we highlight the important of human capital development plays in influencing environmentally-driven urbanization. By making investments in education, knowledge-based economies, and skill-building programs, urban residents may adopt sustainable lifestyles and advance eco-friendly urban

TABLE 10 Slope coefficients estimation results.

Variables	MG	DOLSMG	CCE	AMG	CS-ARDL (SR)	CS-ARDL (LR)
LNGDP	0.007	0.158	0.017	−0.046	−0.058	−0.031
LNMVA	−0.139	−0.334***	−0.121	0.027	−0.200*	−0.102*
LNURB	1.462	1.291	10.519	0.406	14.66	7.87
LNHCD	1.670**	2.254***	1.997*	1.167*	2.03***	1.054***
LNRE	−0.176*	−0.023*	−0.081	−0.173*	−0.110	−0.058

Note: *, **, and *** depict 10%, 5%, and 1% significance, respectively. SR, means shorth-run while LR, indicates long-run.

TABLE 11 Panel Fisher causality tests.

The null hypothesis→	LNGDP≠> LNCO2		LNMVA≠> LNCO2		LNURB≠> LNCO2	
Country	*Wald*	*p-val*	*Wald*	*p-val*	*Wald*	*p-val*
Morocco	0.040 (1)	0.842	4.815 (3)	0.186	2.042 (2)	0.36
Tunisia	1.516 (1)	0.218	1.034 (2)	0.596	6.463 (3)*	0.091
Egypt	1.261 (1)	0.261	0.736 (3)	0.865	4.751 (3)	0.191
Jordan	0.603 (2)	0.437	19.60 (3)***	0.000	3.114 (3)	0.374
Saudi Arabia	10.411 (1)***	0.001	6.88 (2)**	0.032	6.337 (3)*	0.096
Lebanon	1.516 (2)	0.615	2.246 (1)	0.134	5.861 (3)	0.119
Panel Fisher		24.135		32.58		21.054
Asymptotic p-value		0.019**		0.001***		0.050*
Bootstrap p-value		0.264		0.000***		0.975
The null hypothesis→	LNHCR≠> LNCO2		LNRE≠> LNCO2			
Country	*Wald*	*p-val*	*Wald*	*p-val*		
Morocco	0.924 (1)	0.336	0.058 (1)	0.810		
Tunisia	0.177 (2)	0.915	6.705 (2)**	0.035		
Egypt	4.933 (3)	0.177	1.389 (3)	0.708		
Jordan	3.291 (3)	0.349	4.985 (3)	0.173		
Saudi Arabia	9.569 (3)**	0.023	0.859 (3)	0.835		
Lebanon	8.811 (2)	0.012	2.038 (1)	0.153		
Panel Fisher		24.318		15.437		
Asymptotic p-value		0.018**		0.218		
Bootstrap p-value		0.983		0.006***		

Note: *, **, and *** depict 10%, 5%, and 1% significance, respectively. We selected 10.000 number of bootstrap replications while we employed Akaike information criterion. Numbers in parenthesis states lag-length.

planning. The major impact of human capital development should be considered by decision-makers and urban planners when developing strategies to deal with the environmental issues arising by increasing urbanization. Big cities can create the conditions for future economic growth that is more ecologically friendly and sustainable by encouraging the development of an informed and competent urban populace.

In conclusion, in the MENA region's urbanization highly complex driven by diverse issue but more influenced by human capital and manufacturing activities development. Various factors, including economic liberalization, the spread of clean technologies, poverty, and access to financial services, have influence the interaction between economic development, human capital, manufacturing activities, and environmental degradation. In order to create effective policies and strategies to advance sustainable urbanization in the area, it is essential for further studies to pay to environmentally-driven urbanization processes in the MENA region.

5.2 Policy implications

Our empirical results offer different policy implications towards enhancing environmental quality in the MENA region. To ensure sustainable urbanization and energy consumption in MENA countries, there is a need to put in place an urban development policy capable of accommodating the rate of urbanization, and an energy policy that will ensure the sustainability of the energy consumption in the long-run. Furthermore, there is a need for industrial sector transformation towards the green economy to combat the environmental challenges emanating from economic growth. The countries in MENA region should enforce their rules and regulations regarding the conservation of the environment so that environmental health is more emphasized. Finally, to achieve urbanization sustainability, effective energy, economic, and environmental policies are required to guide the rate of urbanization towards the reduction ofCO2 emissions to achieve

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better environmental quality, without compromising economic growth. Therefore, policymakers in urban planning should aim at reducing the urbanization level by practicing effective land use to encourage green and intelligent urbanization. This will ameliorate the influence of urbanization on environmental degradation. Despite the study's considerable contribution to environmental literature, particularly in MENA region, it has several drawbacks such as the use of only five indicators for the analysis. Therefore, we recommend that future research incorporate more parameters and investigate their impact on various environmental metrics.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/Supplementary material.

Author contributions

SB: Conceptualization, Data curation, Formal Analysis, Writing–original draft. HR: Writing–review and editing. AC: Formal Analysis, Methodology, Writing–review and editing. FD: Writing–review and editing. SD: Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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