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Driving Environmental and Business Sustainability in the MENA Region: The Role of Global Innovation, Finance, Governance, and Quality

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ABSTRACT

Purpose- This research aims to identify the critical factors influencing environmental and business sustainability in the Middle East and North Africa (MENA) region. It emphasizes the roles of global innovation, governance, finance, and environmental quality, considering the region's unique challenges, such as reliance on fossil fuels, environmental degradation, and increasing climate risks. The study explores how businesses and policymakers can harness these factors to foster sustainable practices, reduce carbon emissions, and build long-term economic resilience.

Design/Methodology/Approach- The study employs the Panel Quantile Autoregressive Distributed Lag (QARDL) model to examine the short- and long-term effects of global technological advancements, governance quality, financial development, and other causal factors on carbon emissions across various emission levels (quantiles).

Findings- The findings indicate that global innovation in green business practices consistently reduces emissions across all levels, particularly in higher-emission countries. Conversely, economic growth increases emissions, with the effect being more pronounced in nations with higher emissions. Governance, including regulatory support, policy alignment, and corporate responsibility mechanisms, is linked to higher emissions, especially in low- and high-emission contexts. Financial development is shown to increase emissions, except for higher quantiles in the long run. This study provides a comprehensive view of the strategies businesses and governments in the MENA region.

Discussion- This study highlights the interconnectedness of innovation, governance, finance, and environmental quality in promoting sustainable business practices in the MENA region. It underscores the need for effective governance measures, including supportive policies and incentives, to encourage innovation and facilitate the widespread adoption of sustainable technologies. Businesses should align their sustainability strategies with regional policies and global innovations to effectively tackle environmental and economic challenges. The study concludes with policy recommendations for businesses and governments to create a conducive environment for sustainable development, emphasizing the need for a comprehensive approach that integrates innovation, governance, green financing, and environmental stewardship.

1. INTRODUCTION

The MENA (Middle East and North Africa) region is at a critical juncture in its pursuit of both environmental sustainability and business sustainability. As the region faces growing environmental challenges, including water scarcity, air pollution, and increasing greenhouse gas emissions, there is a pressing need to rethink the traditional models of economic growth and business practices. According to the Intergovernmental Panel on Climate Change (IPCC), limiting global warming to 1.5°C above pre-industrial levels requires net-zero emissions by mid-century (IPCC, 2018). The transition toward sustainable business practices is not only a matter of ecological responsibility but is increasingly seen as a key driver of long-term economic resilience, competitiveness, and global integration. The MENA region's dependency on fossil fuels has long been a cornerstone of its economic growth, but this reliance also makes it vulnerable to climate change and the global shift toward a low-carbon economy. Thus, the challenge for MENA countries is to foster a transition to carbon neutrality while maintaining economic stability and business viability.

Global innovation, particularly in the realms of renewable energy, clean technologies, and sustainable business models, has the potential to significantly reduce the region's carbon footprint while driving economic growth. Technological advancements can help businesses in MENA optimize their operations, reduce costs, and adopt environmentally friendly practices that meet the rising expectations of global consumers and investors.

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However, innovation alone is insufficient to achieve sustainable change. The role of governance is paramount in ensuring that the right policies, regulations, and incentives are in place to guide businesses toward sustainable practices. Effective governance not only provides the legal and regulatory framework necessary for innovation but also facilitates collaboration between public and private sectors to address complex sustainability challenges.

At the same time, environmental quality in MENA countries is a critical determinant of business performance and societal well-being and is deteriorating due to urbanization, industrial growth, and resource exploitation (Al-Mulali and Sab, 2012). Poor environmental conditions, such as air and water pollution, directly impact public health and labor productivity, which in turn affect business operations and profitability. Businesses that prioritize environmental quality not only contribute to the region's overall sustainability but also benefit from enhanced reputations, improved employee morale, and access to sustainable investment opportunities (Alsayegh et al., 2020). The integration of global innovation, effective governance, and a focus on environmental quality is, therefore, crucial for driving business sustainability and ensuring long-term economic prosperity in the MENA region (Zhang et al., 2017).

However, the shift toward sustainability presents significant opportunities for businesses to innovate and align with global climate goals. Global innovation in green technologies, renewable energy, and sustainable business practices offers pathways for MENA companies to reduce their environmental impact while fostering growth. Alongside innovation, effective governance plays a pivotal role in enabling this transition. Strong regulatory frameworks, green financing, and corporate governance mechanisms are essential in facilitating the adoption of carbon-neutral strategies. On the one hand, its economic dependence on fossil fuels makes the transition to cleaner energy more difficult (Bölük and Mert, 2014). Likewise, the region possesses abundant green energy resources, like solar and wind, which can serve as the foundation for a decarbonized economy and long-term business viability (Lilliestam and Patt, 2015).

The MENA region is among the most climate-vulnerable areas globally, grappling with severe environmental challenges driven by climate change. Rising temperatures, water scarcity, and frequent extreme weather events position it as one of the region's most at risk (World Bank, 2014). If global average temperatures rise by 4°C above pre-industrial levels, the MENA region could regularly experience extreme heat reaching up to 56°C. These higher temperatures put additional pressure on ecosystems, which are already fragile due to the region's predominantly arid and semi-arid landscapes. The agricultural sector, heavily dependent on rainfall for 70% of its activity, is particularly vulnerable. As the primary source of employment in many countries, agriculture plays a vital role in the region's economies. However, a global temperature increase of 2°C could result in substantial agricultural losses, leading to billions in reduced household incomes. For instance, losses could amount to $2 billion in Syria and Tunisia and escalate to $9 billion in Yemen alone (IPCC, 2022).

Another factor that heightens MENA's vulnerability is its economic based on fossil fuels. The economies of MENA's resource-rich nations heavily rely on the oil and gas trade, with fossil fuels accounting for an average of 50% of exports in countries such as the GCC states, Iraq, Libya, and Iran. Many countries in the region rely heavily on oil and gas exports as their primary source. This financial structure makes it difficult to transition to sustainable energy systems and exposes these economies to global shifts in energy demand as the world moves towards decarbonization. In this context, the transition towards carbon neutrality is crucial for achieving both environmental sustainability and long-term economic resilience. The role of global innovation and environmental quality is paramount in promoting this transition, especially in a region with untapped potential in renewable energy and green technologies (Zinecker et al., 2018).

In the MENA region, green energy sources account for less than 1.5% of total electricity generation, compared to a global average of 10% (Andriamahery and Qamruzzaman, 2022). However, due to the region's substantial renewable energy potential, MENA has the opportunity to decarbonize its energy systems, bringing considerable socio-economic and environmental advantages. Innovation plays a critical effect on driving the shift toward carbon neutrality and ensuring long-term business sustainability. Technological innovations in energy efficiency, green energy significantly decrease CO_2 emissions and promote sustainable development (Acemoglu et al., 2012). For instance, solar energy innovations have already begun transforming the MENA energy landscape, with projects like Noor in Morocco and Masdar City in the UAE demonstrating the potential for large-scale renewable energy adoption (Miketa and Merven, 2013). Furthermore, green technology

diffusion, particularly through international partnerships and investments, offers MENA countries access to cutting-edge solutions that can help overcome their dependence on fossil fuels (Popp, 2019). Studies suggest that countries with stronger innovation capacity and investment in R&D are better positioned to achieve carbon neutrality (Costantini et al., 2013).

This study explores the pathways to carbon neutrality and business sustainability in the MENA region, focusing on the roles of global innovation, finance, governance and quality. This study investigates how technological advancements and governance structures support the region's businesses in navigating the challenges of reducing carbon emissions and achieving sustainability. The main purpose of this study is to investigate how businesses in the region can transition toward carbon-neutral practices and green financing while maintaining long-term sustainability in the face of global environmental challenges.

This study contributes to the literature by exploring the pathways to carbon neutrality and business sustainability in the MENA region, with a particular focus on the roles of global innovation, finance, governance, and environmental quality. It investigates how technological advancements and governance structures can help businesses in the region overcome challenges related to reducing carbon emissions and achieving long-term sustainability. By identifying specific sustainable business strategies such as eco-design, waste reduction, sustainable supply chain management, and circular economy models. The study provides practical insights into how businesses in the MENA region can integrate sustainability while maintaining profitability. Moreover, it demonstrates how aligning business goals with sustainability objectives can create significant value, driving innovation, optimizing resource use, investing in green financing, and improving operational efficiency in the long term. This study fills a critical gap by offering a region-specific perspective, showing how MENA businesses can transition to carbon-neutral practices and sustainable growth, ultimately contributing to both environmental and economic resilience.

Furthermore, in terms of sustainable business strategies, the study provides valuable insights into the specific approaches that businesses in the MENA region can adopt to integrate sustainability. The study identifies key strategies such as eco-design, waste reduction, sustainable supply chain management, and circular economy models that businesses reduce their environmental impact while maintaining profitability. Furthermore, the study demonstrates how aligning business goals with sustainability objectives create significant value for companies. By prioritizing sustainable practices, businesses drive innovation, optimize resource use, invest in in green financing, and improve long-term operational efficiency.

The remainder of the study is structured as follows: Section 2 provides a literature review and an in-depth examination of the relevant literature on the study variables. The data sources is outlined in Section 3. Later, Section 4 shows empirical results. Finally, Section 5 concludes with policy recommendations.

2. LITERATURE REVIEW

Achieving carbon neutrality has become a crucial global objective, motivated to address climate change and lower CO_2 emissions. The MENA region, characterized by its reliance on oil exports and fossil fuel consumption, faces unique challenges and opportunities in transitioning toward carbon neutrality. Existing literature emphasizes that MENA countries must balance economic growth with sustainability by adopting green technologies and improving environmental policies (Albaker et al., 2023; Gang et al., 2023; JinRu & Qamruzzaman, 2022). The Paris Agreement has further intensified this global commitment, with MENA nations increasingly recognizing the need for a low-carbon transition, despite structural economic hurdles (Saidi and Omri, 2020).

Global innovation, especially in green energy and green technologies, is instrumental in enabling carbon neutrality. There are several studies that conclude technology transfer and innovation diffusion are critical for developing countries like those in the MENA region, where domestic innovation capacity remains limited. For instance, Alvarado et al. (2024) explore how innovation and financial efficiency affect environmental quality, examining the roles of production per capita, FDI, natural resource rents, and institutional quality. Their findings indicate that technology is more closely linked to enhancing production output than to reducing or reversing environmental degradation. Moreover, Albaker et al. (2023) analyze CO_2 emissions in the MENA region, focusing on green energy, energy intensity, green innovation, and economic expansion. They find that

green energy lowers emissions across all levels, while energy intensity, innovation, and economic expansion increase emissions.

Another focus in the literature is technology transfer, which enables MENA countries to access global innovations necessary for carbon neutrality. Hao et al. (2020) use spatial econometrics to investigate the effect of FDI and technological transfer on pollution in China. They conclude that FDI reduces pollution, while technological transfer lowers CO_2 emissions. Recently, Alnafisah et al. (2024) examine how technological innovation, green energy, and economic growth impact CO_2 emissions in MENA countries. Their findings confirm an inverted U-shaped linkage between patents and emissions.

Several studies indicate that CO_2 emissions in the MENA region are strongly linked to its green energy and economic and financial development. Charfeddine and Kahia (2019) investigate the effects of green energy and financial development on CO_2 emissions and economic development in 24 MENA nations. The findings reveal that green energy use and financial development have minimal effect on CO_2 emissions and economic development. Later, Ben Cheikh et al. (2021) examine CO_2 emissions, energy use, and income in the MENA region. Their findings reveal an inverted U-shaped effect where environmental degradation decreases past a certain income threshold, and that GDP growth raises emissions significantly only when energy consumption growth is high. Furthermore, Gaies et al. (2022) analyze how globalization affects CO_2 emissions in 17 MENA countries. Globalization increases emissions, especially through trade, with no effect from decreases.

The existing literature highlights that the pursuit of carbon neutrality in the MENA region requires an integrated approach that considers environmental quality, economic structure, policy frameworks, and technological innovation. Abdouli and Hammami (2017) investigates how FDI, capital stock, and environmental quality impact economic expansion in 17 MENA countries. Their empirical findings show that FDI and capital stock promote growth, while environmental degradation hinders it. Moreover, Ayad et al., (2023) examine how economic policy uncertainty affects environmental quality in selected MENA countries from 1970 to 2020, employing an augmented STIRPAT model. Findings indicate that increased economic uncertainty leads to higher CO_2 emissions, particularly in Morocco, Turkey, and Iran, supporting the Environmental Kuznets Curve (EKC) hypothesis. Xu and Hussain (2023) explore how globalization and institutional quality affect environmental sustainability in 14 MENA countries. Their results support that globalization, political stability, and financial development control lower carbon emissions, while energy production, financial and economic development increase them. Lastly, Gang et al. (2023) explore the effects of environmental investment and energy efficiency on sustainability within the MENA region. Their findings conclude that these factors significantly enhance sustainability.

In the same vein, Awan et al. (2020) assess the effects of globalization and financial development on CO_2 emissions in selected MENA economies and confirms the EKC hypothesis. The findings conclude that both factors enhance CO_2 emissions. Kahia et al. (2017) examine the impact of green energy policies on economic development in MENA countries using propensity score matching. Their findings show that these policies significantly boost growth in countries that have adopted them. Recently, Said and Acheampong (2024) analyze the effect of financial inclusion and green energy on CO_2 emissions in 11 MENA countries. They find that financial inclusion aids decarbonization, though its effects differ across countries, and renewable energy significantly reduces emissions. Xian et al. (2024) investigate the impact of environmental policy and eco-innovation on CO_2 emissions in G7 countries. They conclude that both significantly reduce emissions over the long term, with environmental policy effective across all quantiles, while eco-innovation is only significant in the 40th to 70th quantiles.

In line with these findings, a recent study by Mtiraoui et al. (2024) explores the regulatory and policy challenges in the MENA region, demonstrating that despite the increasing adoption of green technologies, inconsistent environmental policies and insufficient regulatory frameworks remain significant barriers to the region's transition to sustainability. Their research calls for stronger governance structures, comprehensive environmental policies, and regional cooperation to ensure effective implementation of sustainability initiatives and carbon reduction measures.

Another important aspect raised in recent literature is the economic and social implications of the green transition. According to a study by Khaled et al. (2024), while transitioning to carbon neutrality offers significant long-term economic and environmental benefits, the short-term economic disruptions, particularly in fossil-fuel-dependent sectors, pose considerable challenges for MENA countries. Their research suggests that a just transition approach is necessary, one that addresses the social and economic impacts on communities reliant on oil and gas industries, ensuring that the benefits of green growth are widely distributed.

Furthermore, new research by Said and Acheampong (2024) investigates the role of green financing in facilitating the transition to a low-carbon economy in the MENA region. They find that while there is growing interest in green bonds and sustainable investment funds, the region still faces challenges in accessing adequate financing for large-scale green energy projects. Their study calls for the establishment of regional green financial institutions and stronger partnerships with international financial bodies to unlock the necessary capital for transitioning to a carbon-neutral economy.

Additionally, Jin and Huang (2024) explore the analysis of natural resources on environmental sustainability in the MENA region, focusing on green growth. They indicate that the region benefits from a resource boon, with financial technologies (FINTECH) playing a key role in enhancing this effect. Moreover, Zhou et al., (2024) examine the role of environmental regulations (ER) in moderating the effects of financial development and investments on the ecological footprint in the MENA region. Their empirical findings indicate that while financial development reduces ecological footprint, foreign direct investment inflows increase it.

While significant research has been conducted on environmental and business sustainability at a global level, there remains a notable gap in understanding how these factors intersect specifically within the context of the MENA region. The unique economic, political, and environmental conditions in MENA, such as the region's heavy reliance on fossil fuels, water scarcity, and political complexities, present challenges that differ from those faced by other regions in the transition to sustainability.

Most studies on business sustainability have predominantly focused on developed economies or other emerging markets, often neglecting the unique dynamics, challenges, and opportunities within the MENA region. While there is extensive research on the role of global innovation in driving sustainability, limited attention has been given to how green energy advancements, green technologies, and sustainable business models can be specifically adapted, implemented, and scaled in the MENA context. This gap is critical, as the region's heavy reliance on fossil fuels and its socio-economic complexities require tailored solutions.

Furthermore, although innovation is universally recognized as a cornerstone of sustainable development, the pivotal role of governance in facilitating this transformation remains underexamined in the MENA region. Governance structures, including regulatory frameworks, policy incentives, and institutional support, are essential for enabling businesses to integrate sustainability into their operations effectively. However, the mechanisms by which governance fosters the adoption of sustainable practices, mitigates barriers, and aligns with regional characteristics are not well understood. Addressing these gaps is crucial for crafting strategies that not only drive sustainability but also ensure they are practical and impactful within the socio-political and economic realities of the MENA region.

3. DATA INFORMATION

The P-QARDL model builds upon the traditional ARDL framework by integrating it into a quantile regression approach. This enhancement allows for a more comprehensive analysis of the relationship between variables, as it enables the examination of the effects across different quantiles of the conditional distribution of the dependent variable, rather than just focusing on the mean. By incorporating the quantile regression method, the P-QARDL model is able to capture the potential heterogeneous effects of the regressors on the dependent variable at various points of the distribution, such as the lower, median, and upper quantiles. The P-QARDL model improves upon traditional ARDL models by offering a richer and more detailed analysis of the relationships in the data, accommodating the complexities inherent in real-world economic and financial systems. Using the logarithm for the variables, a Quantile panel ARDL regression is expressed below:

$$QLNCO2_{\boldsymbol{t}} = \alpha(\tau) + \sum_{\mathrm{l}=1}^{\rho} \vartheta_i(\tau) LNCO2_{t-i} + \sum_{i=0}^{q_1} \beta_i(\tau)\, LNGII_{t-i} + \sum_{i=0}^{q_2} \theta_i(\tau)\, LNEPI_{t-i} + \sum_{i=0}^{q3} \pi_i(\tau)\, LNGDP_{t-i} + \sum_{i=0}^{q4} \gamma_i(\tau) LNREC_{t-i} + \sum_{i=0}^{q5} \delta_i(\tau) LNGOV_{t-i} + \sum_{i=0}^{q_6} \mu_i(\tau)\, LNFIN_{t-i} + \varepsilon_t(\tau)$$

mathematically as follows:

$$\Delta LNCO2_{it} = \alpha + \rho_1 \Delta LNCO2_{it}^{\theta} + \rho_2 \Delta LNGII_{it}^{\theta} + \rho_3 \Delta LNEPI_{it}^{\theta} + \rho_4 \Delta LNGDP_{it}^{\theta} + \rho_5 \Delta LNREC_{it}^{\theta} + \rho_6 \Delta LNGOV_{it}^{\theta} + \rho_7 LNFIN_{it}^{\theta} + \varepsilon_t^{\theta}$$

Table 1 presents the average values of the variables for each country in the MENA region over the period from 2013 to 2022. The mean values are calculated by aggregating the data for each variable across the entire period for each country. Notably, Israel, the UAE, and Türkiye have the highest average scores for the global innovation index, indicating that these countries are leading in terms of technological advancements, research, and development activities. On the other hand, Qatar, Bahrain, and the UAE exhibit the highest average CO2 emissions over the same period, suggesting that these countries face significant challenges in reducing their carbon footprints despite their advancements in other areas. This contrast highlights the complex relationship between innovation and environmental impact, where some countries may lead in technological progress but still experience high levels of emissions, often due to industrial activity, energy consumption patterns, and economic structures reliant on fossil fuels.

This study utilizes a yearly panel dataset spanning nine years, from 2013 to 2022, and focuses on 16 countries within the MENA region. The selection of these countries and time frame is guided by the availability and reliability of data during the specified period. The dataset allows for a comprehensive analysis of environmental and economic dynamics in the region.

Details about the variables used in the study, including their names, codes, definitions, and data sources, are summarized in Table 2. This table provides a clear overview of the indicators included in the analysis, ensuring transparency and reproducibility of the study.

Table 1. The means of variables by country for the period 2013-2022

Country	LNCO	LNGII	LNEPI	LNGDP	LNREC	LNGOV	LNFIN
Algeria	3.83	22.45	54.15	3.67	0.12	6.62	2
Bahrain	21.95	32.82	57.30	4.40	1.245	7.18	2.64
Egypt	2.197	26.61	56.63	3.50	5.64	7.94	2
Iran	3.91	30.89	54.84	3.65	0.95	6.41	1.5
Israel	7.26	54.25	70.45	4.62	4.46	6.95	3.5
Jordan	2.42	31.17	59.85	3.61	6.84	7.66	2.87
Kuwait	22.0	33.46	60.41	4.52	0.04	6.17	2.76
Lebanon	4.28	29.91	55.05	3.84	5.175	6.09	1.67
Morocco	1.79	31.11	56.10	3.52	11	6.98	2.75
Oman	16.23	31.27	48.18	4.29	0.03	9.30	2.85
Qatar	33.44	36.14	57.44	4.84	0.03	9.95	3.25
Saudi Arabia	15.58	36.08	57.79	4.36	0.03	8.06	2.93
Tunisia	2.57	32.06	59.60	3.57	12.365	6.52	2.72
Türkiye	4.76	37.55	53.15	4.01	12.765	7.65	2.54
UAE	20.75	41.95	63.46	4.64	0.3	10.06	3.80
Yemen	0.48	16.21	39.07	2.961601	2.59	6.17	1.26
Total	10.21	32.74	56.47	4.01	3.97	7.48	2.56

Table 2 presents a set of variables with definitions and sources, including CO_2 emissions per capita and Global Innovation Index sourced from the World Intellectual Property Organization (WIPO). The Environmental Performance Index reflects the efficiency of energy usage relative to GDP per capita, while GDP per capita indicates economic output per individual in US dollars. Renewable energy consumption measures the percentage of energy from green sources, and governance ratings assess the political and ethical environment of a country. Lastly, financial development is computed as a weighted index of the private sector credit, stock market, and total debt as a share of GDP.

Table 2. Data Informations

Indicators	*Definition*	*Source*
Carbon Emissions	CO2 emissions (metric tons per capita)	WDI
Global Innovation Index	Total of 80 indicators for GII	WIPO
Environmental Performance Index	The ratio of GDP per capita to total primary energy consumption	WDI
GDP per capita	GDP per capita (current US$)	WDI
Renewable Energy Consumption	Renewable energy consumption (% of total final energy consumption)	WDI
Governance	International Country Risk Guide	PRS Group (2022)
Financial development Index	Private sector credit, stock market, and total debt as a share of GDP	IMF

Figure 1 presents a time-series depiction of the total CO_2 emission levels in MENA countries from 2013 to 2022. The per capita CO_2 emissions graph reveals a steady decline in emissions from 2013 to 2017. However, after 2017, the trend stabilizes, showing minor fluctuations and maintaining a relatively consistent level of emissions through 2022. This trend suggests that MENA countries may have implemented measures to reduce emissions up until 2017, but further reductions were limited after that period.

Additionally, Figure 2 illustrates a time-series depiction of the overall levels of renewable energy consumption in MENA countries from 2013 to 2022. The graph shows a gradual increase in the share of renewable energy in total energy consumption, indicating growing efforts by MENA countries to integrate renewable energy sources into their energy mix.

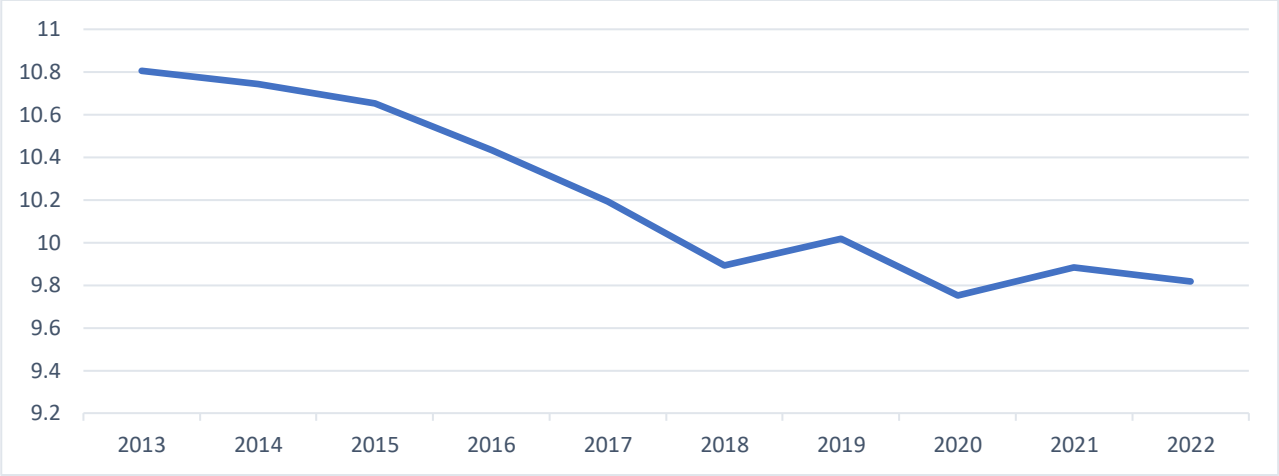

Figure 1. CO_2 emissions per capita in MENA countries (**Source:** Author's own elaboration)

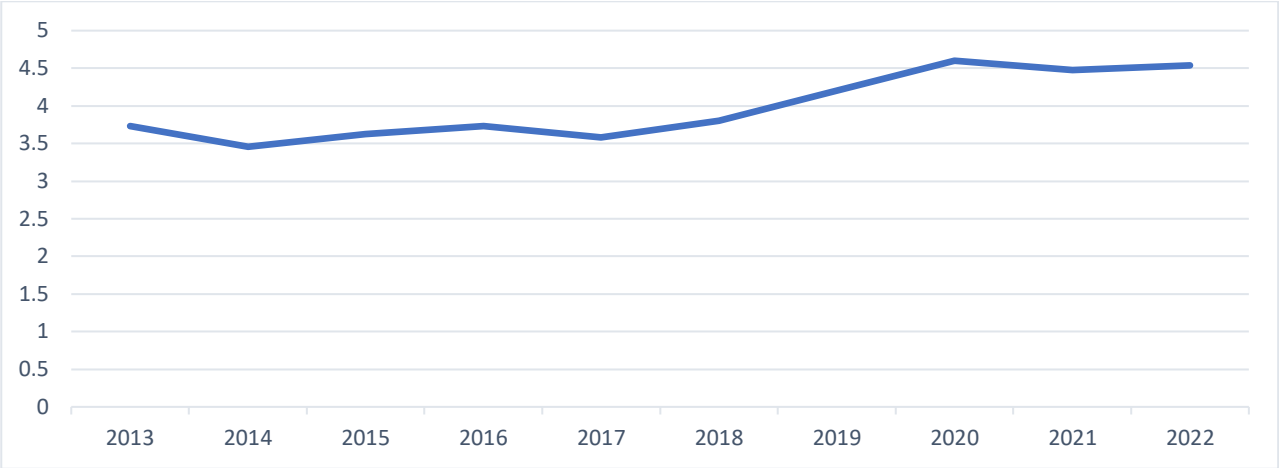

Figure 2. Renewable energy consumption in MENA countries (**Source:** Author's own elaboration)

The Global Innovation Index (GII) assesses and ranks countries based on their innovation capacity across around 80 indicators. It covers seven key areas: Institutions, which examines the political, regulatory, and business environment; Human Capital and Research, assessing education systems, research activity, and knowledge creation; Infrastructure, focusing on physical and digital resources necessary for innovation; Market Sophistication, evaluating financial and investment systems; Business Sophistication, analyzing the adaptation of innovative practices within businesses; Knowledge and Technology Outputs, measuring tangible innovation results like patents and productivity improvements; and Creative Outputs, which captures cultural production, trademarks, and content creation. The GII helps countries understand and improve their innovation ecosystem, driving competitiveness and economic growth. Figure 3 represents a time-series depiction of the overall levels of global innovation index in the MENA countries from 2013 to 2022.

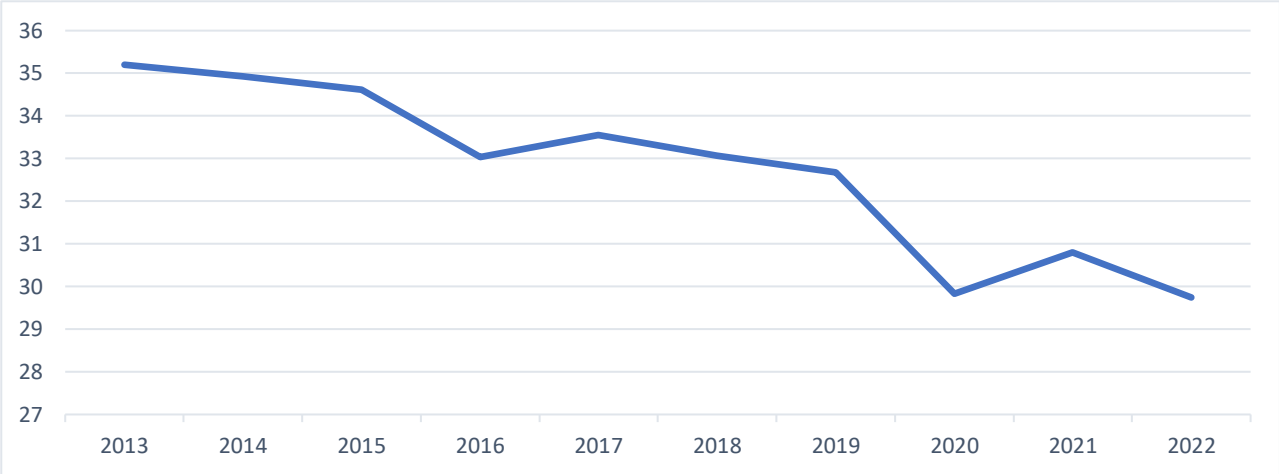

Figure 3. Global Innovation Index in MENA (**Source:** Author's own elaboration)

Furthermore, the Environmental Performance Index (EPI) serves as a comprehensive tool for assessing and ranking countries' environmental performance by consolidating a wide range of indicators into three primary dimensions. These are: Environmental Health, which focuses on aspects that directly affect human health, such as air quality, sanitation, and exposure to pollution; Ecosystem Vitality, which evaluates efforts to preserve natural resources and ecosystems, including biodiversity, climate change mitigation, and sustainable resource use; and Climate Change Mitigation (Block et al., 2024).

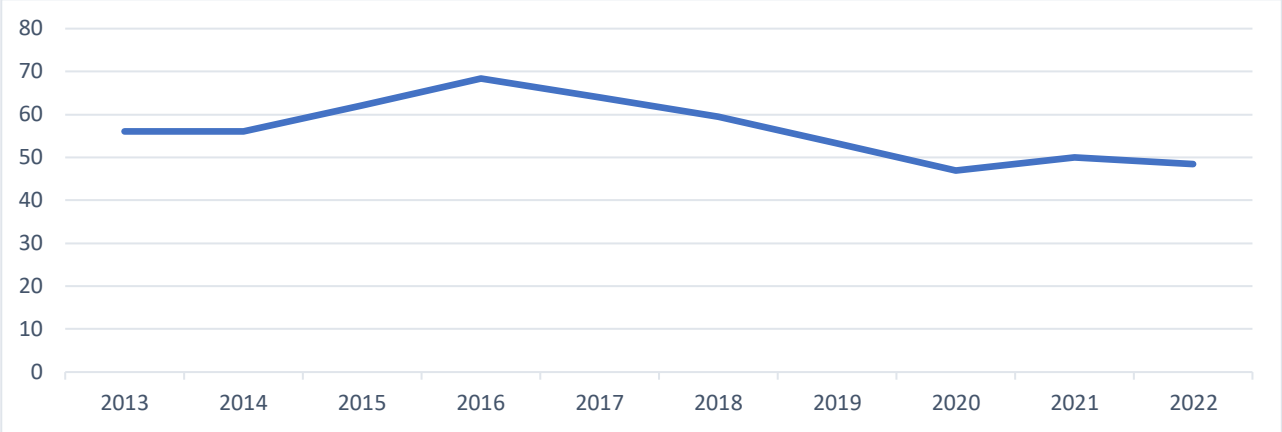

Figure 4. Environmental Performance Index in MENA (**Source:** Author's own elaboration)

4. EMPIRICAL RESULTS

This study analyzes the influences of global innovation, environmental performance, economic development, renewable energy consumption, governance, and financial development on environmental degradation in the MENA region. Table 3 presents the descriptive statistics for variables used in this study. The descriptive statistics offer a summary of the data distribution and emphasize the variability within the MENA region. The JB estimates also confirm the non-normality of the variables.

Table 3. Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.	Jarque–Bera	Prob. value
LNCO	160	10.21	9.72	0.308	37.60	24.5	0.0000
LNGII	160	32.74	8.503	13.6	57.4	27.85	0.0000
LNEPI	160	56.47	10.09	30.16	78.14	11.19	0.0000
LNGDP	160	4.01	0.525	2.76	4.98	8.408	0.0052
LNREC	160	3.97	4.584	0	14.1	24.64	0.0000
LNGOV	160	7.48	1.33	5.01	10.5	14.1	0.0000
LNFIN	160	2.56	0.744	1	4.2	6.184	0.0011

After descriptive statistics, Table 4 presents the correlation estimates for all variables. There is a negative correlation between renewable energy consumption and CO_2 emissions, while all other variables have positively correlated with CO_2 emissions.

Table 4. Correlation matrix

Variable	LNCO	LNGII	LNEPI	LNGDP	LNREC	LNGOV	LNFIN
LNCO	1.0000						
LNGII	0.3469*	1.0000					
LNEPI	0.1741*	0.6097*	1.0000				
LNGDP	0.8436*	0.7114*	0.3728*	1.0000			
LNREC	-0.5846*	0.0189	0.0066	-0.4286*	1.0000		
LNGOV	0.5860*	0.3130*	0.1247	0.5268*	-0.2678*	1.0000	
LNFIN	0.5200*	0.6680*	0.3025*	0.7122*	-0.0338	0.5461*	1.0000

Note: * denotes significance at 5% level.

When the time dimension is smaller than the cross-sectional dimension (T < N), the Pesaran (2004) CD and CD LM test is applied. In this study, since there are 16 countries (N=16) and 9 years (T=9), the Pesaran (2004) CD-CDLM test has been used. Table 5 indicates the acceptance of cross-sectional dependency in each variable and model as well.

Table 5. Cross-sectional Dependence Test

variable	CD test	P-value	CD_{LM} test	P-value
LNCO	5.42***	0.000	10.13***	0.000
LNGII	14.27***	0.000	7.79***	0.000
LNEPI	27.02***	0.000	9.329***	0.000
LNGDP	11.61***	0.000	9.472***	0.000
LNREC	5.97***	0.000	8.964***	0.000
LNGOV	6.10***	0.000	6.345***	0.000
LNFIN	5.55***	0.000	4.314***	0.000
Model*	38.35***	0.000	8.503***	0.000

Note: ***, **, and * show significance at the 1%, 5% and 10% levels.

In light of cross-sectional dependence, we utilize second-generation unit root tests using the CSD-adjusted Im-Pesaran-Shin (CIPS) test and the Pesaran Augmented Dickey-Fuller (CADF) test. The results shown in Table 6 consistently demonstrate the existence of a unit root, both with and without a trend, across all tests, except for LNREC, LNGOV and LNCO, which are stationary at their original levels. As a result, the unit root tests indicate a mixed level of integration among the variables.

Table 6. Unit Root Tests

Series	Model	CIPS (at the level)	CIPS (at the first difference)	CADF (at the level)	CADF (at the first difference)
LNCO	Constant	-2.454**	-2.697***	-4.288***	-3.214***
	Constant&Trend	-2.392	-2.517**	-3.163*	-2.730***
LNGII	Constant	-1.522	-2.702***	-1.811	-2.677***
	Constant&Trend	-1.451	-3.833***	-2.236	-3.236***
LNEPI	Constant	-1.685	-2.981***	-1.345	-5.512***
	Constant&Trend	-1.442	-2.336***	-2.395*	-5.844***
LNGDP	Constant	-1.582	-2.545*	-1.912	-5.1352***
	Constant&Trend	-1.195	-2.744**	-1.787	-2.6341***
LNREC	Constant	-2.600***	-3.544***	-1.352	-3.053***
	Constant&Trend	-3.378***	-3.346***	-3.092***	-3.703***
LNGOV	Constant	-3.724***	-4.004***	-4.452***	-4.405***
	Constant&Trend	-3.684***	-4.633***	-4.735***	-4.730***
LNFIN	Constant	-1.252	-2.234*	-1.990	-3.627***
	Constant&Trend	-1.553	-2.660**	-2.208	-2.730***

Note: ***, **, and * presents significance at the 1%, 5% and 10% levels.

To establish the presence of a long-term relationship, a cointegration test was conducted, with the results detailed in Table 7. The outcomes of the cointegration analyses, based on three methods as seen in the table. The results confirm a significant long-term association between CO_2 emissions and all the indicators.

Subsequently, the P-QARDL results, which analyze the short-run relationships among global innovation, environmental performance, economic growth, renewable energy consumption, governance, and financial development with environmental degradation, are presented in Table 8. The estimates in Table 8 are consistent with the original P-QARDL results in terms of the coefficient signs. The values in parentheses represent the standard errors. Additionally, the Error Correction Term (ECT) is both negative and statistically significant across all quantiles, indicating a stable long-term equilibrium relationship and a fast adjustment process back to equilibrium.

The coefficients of LNGII are positive and significant across the 40th to 80th quantiles, indicating that innovation positively influences CO_2 emissions in the short run, especially in the middle quantiles. This suggests that in countries with moderate levels of carbon emissions, higher innovation might result in an increase in emissions.

Table 7. Cointegration Tests

Test	Test stat.	Prob.
Phillips–Perron t (Pedroni)	-22.0997	0.0000***
Dickey-Fuller t(Kao)	-3.1613	0.0008***
Augmented Dickey-Fuller t (Kao)	-4.1064	0.0000***
Modified Dickey–Fuller t (Kao)	-3.1933	0.0000***
Variance ratio (Westerlund)	1.6486	0.0496**

Note: ** and *** show at 5% and 1% sig. level.

The coefficients for LNEPI are mostly positive but not significant across most quantiles. This suggests that in the short run, improvements in environmental performance do not have a strong or consistent influence on CO_2 emissions within the different quantiles. The coefficients for LNGDP are positive and significant at the 10th, 20th, and 40th quantiles, indicating that economic growth is associated with higher CO_2 emissions in countries with lower to moderate levels of emissions. The impact diminishes and even turns negative in higher quantiles. This reflects the typical environmental Kuznets curve hypothesis, where economic growth initially leads to higher emissions, but this effect diminishes or reverses as countries reach higher levels of development.

Moreover, the coefficients for LNREC are negative but not significant across most quantiles, except for between the 50th and 80th quantiles where it becomes significant. This indicates that in countries with relatively higher emissions, increased renewable energy consumption reduce emissions. The coefficients for LNGOV are mostly positive, but not statistical significance across all quantiles. This concludes that governance does not have a consistent short-run impact on CO_2 emissions across different levels of emissions. The positive coefficients could indicate that as governance increases, carbon emissions might also increase slightly.

Table 8. Short-run P-QARDL Estimates

Δ LNCO							
Quantile	LNGII	LNEPI	LNGDP	LNREC	LNGOV	LNFIN	ECT_{t-1}
10th	0.0461	0.007	2.518**	-0.014	0.094	-0.417	-0.057**
	(0.056)	(0.018)	(1.68)	(0.165)	(0.221)	(0.44)	(0.02)
20th	0.042	0.005	1.353**	-0.027	0.117	-0.465*	-0.051***
	(0.032)	(0.010)	(0.962)	(0.094)	(0.126)	(0.25)	(0.015)
30th	0.041	0.001	0.644**	-0.055	0.0816	-0.140	-0.029**
	(0.031)	(0.010)	(0.947)	(0.092)	(0.124)	(0.247)	(0.015)
40th	0.046**	0.003	0.252**	-0.069	0.086	0.037	-0.023**
	(0.024)	(0.007)	(0.73)	(0.071)	(0.095)	(0.193)	(0.011)
50th	0.0341**	0.002	-0.174	-0.071*	0.065	0.122	-0.011*
	(0.014)	(0.004)	(0.432)	(0.053)	(0.056)	(0.006)	(0.007)
60th	0.027**	0.002	-0.181	-0.074**	0.0759*	0.076	-0.012**
	(0.011)	(0.003)	(0.322)	(0.032)	(0.042)	(0.084)	(0.005)
70th	0.032**	0.003	-0.381	-0.079**	0.017	0.171	-0.013**
	(0.013)	(0.004)	(0.397)	(0.039)	(0.0521)	(0.104)	(0.006)
80th	0.038	0.007	-0.260	-0.1058*	-0.027	0.183	-0.008*
	(0.027)	(0.008)	(0.822)	(0.081)	(0.107)	(0.215)	(0.133)
90th	0.022	0.004	-0.112	-0.109	-0.094	0.137	-0.006*
	(0.034)	(0.011)	(1.02)	(0.101)	(0.134)	(0.268)	(0.016)

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels.

Lastly, the coefficients for LNFIN are positive and significant after the 40th quantile, suggesting that higher levels of financial development in the MENA countries are associated with higher CO_2 emissions in the short run. In countries with higher levels of financial development, environmental regulations are often poorly enforced or selectively applied. Firms may be able to bypass environmental laws through bribes or other corrupt practices, leading to higher emissions as companies face fewer incentives to reduce their carbon footprint.

The ECT coefficients are negative and significant across all quantiles, ranging from -0.057 in the 10th quantile to -0.006 in the 90th quantile. This indicates that there is a short-run adjustment mechanism at work in all quantiles, with the speed of adjustment towards the long-run equilibrium being faster in the lower quantiles and slower in the higher quantiles.

The coefficients for LNGDP are positive and significant across all quantiles, indicating that economic growth is associated with higher carbon emissions in the long run. The coefficients increase as you move from lower to higher quantiles. The coefficients for LNREC are negative and significant in the 20th, 60th, and 80th quantiles. This indicates that higher renewable energy consumption is linked with a reduction in CO_2 emissions in the long run, particularly in the middle quantiles.

In the same vein, the coefficients for LNGOV are positive and significant at the 1% level in the 10th, 20th, 30th, 40th, 50th, and 90th quantiles. This suggests that in the long run, greater governance is associated with higher carbon emissions, particularly in countries with both lower and higher levels of emissions. Later, the coefficients for LNFIN are mostly positive, but not significant across most quantiles, except for the 90th quantile where it is negative and significant. This suggests that in the long run, financial development does not have a consistent impact on emissions, except in the highest quantile where higher financial development is associated with lower emissions.

Table 9. Long-run P-QARDL Estimates

LNCO						
Quantile	LNGII	LNEPI	LNGDP	LNREC	LNGOV	LNFIN
10th	-0.313*** (0.105)	0.001 (0.058)	13.06*** (1.902)	-0.197 (0.137)	1.872*** (0.433)	0.732 (1.055)
20th	-0.315*** (0.051)	0.004 (0.050)	13.98*** (0.935)	-0.155** (0.066)	1.972*** (0.212)	0.224 (0.531)
30th	-0.396*** (0.079)	0.0177 (0.046)	15.99*** (1.43)	-0.146 (0.102)	1.572*** (0.321)	0.862 (0.795)
40th	-0.502*** (0.098)	0.037 (0.054)	16.80*** (1.31)	-0.202 (.1012)	0.871** (0.114)	0.657 (0.042)
50th	-0.092*** (0.006)	0.074 (0.057)	18.29*** (1.89)	-0.221 (0.136)	0.793** (0.431)	0.724 (1.034)
60th	-0.607*** (0.005)	0.570 (0.051)	19.07*** (1.64)	-0.269** (0.074)	0.575 (0.384)	0.421 (0.901)
70th	-0.578*** (0.005)	0.580 (0.052)	19.94*** (1.73)	-0.207* (0.124)	0.569 (0.085)	-0.129 (0.951)
80th	-0.745*** (0.005)	0.112** (0.052)	20.51*** (2.09)	-0.290* (0.074)	0.7606 (0.083)	0.291 (1.31)
90th	-0.643*** (0.005)	0.022 (0.052)	24.28*** (3.23)	-0.083 (0.075)	1.186*** (0.085)	-2.424*** (0.031)

Note: ***, **, and * denote significance at the 1%, 5% and 10% levels.

As outlined in Table 10, the Dumitrescu & Hurlin (2012) Granger non-causality test is applied to examine the directional relationships among the variables, with the results clearly presented. The findings from this test highlight a causal interaction between global innovation, environmental performance, economic growth, renewable energy consumption, governance, financial development, and CO_2 emissions within the MENA region. A bidirectional causality exists among CO_2 emissions and the global innovation index, the environmental performance index, and governance, indicating mutual influence. On the other hand, there is unidirectional causality found from CO_2 emissions to economic growth, from CO_2 emissions to renewable energy consumption, and from CO_2 emissions to financial development.

Table 10. Granger non-causality test

Null Hypothesis	W-Stat	Zbar-Stat	Probability	Decision
LNCO does not cause LNGII	6.6909	16.0962	0.0000	Bidirectional
LNGII does not cause LNCO	2.5331	4.3363	0.0000	
LNCO does not cause LNEPI	4.9606	11.2024	0.0004	Bidirectional
LNEPI does not cause LNCO	2.8556	5.2484	0.0011	
LNCO does not cause LNGDP	3.8361	8.0218	0.0000	Unidirectional
LNGDP does not cause LNCO	2.5256	4.3150	0.4582	
LNCO does not cause LNREC	4.3179	9.3844	0.0000	Unidirectional
LNREC does not cause LNCO	1.2009	0.5683	0.5698	
LNCO does not cause LNGOV	2.6780	4.7462	0.0004	Bidirectional
LNGOV does not cause LNCO	3.8013	7.9232	0.0000	
LNCO does not cause LNFIN	8.3579	4.0369	0.0000	Unidirectional
LNFIN does not cause LNCO	3.2834	1.4250	0.6708	

5. CONCLUSION AND POLICY IMPLICATIONS

This study investigates the role of the roles of global innovation, finance, governance and quality, and causal factors in driving environmental and business sustainability in the MENA region. As the region faces mounting challenges related to climate change, resource scarcity, and the need for economic diversification, the adoption of sustainable business practices is not only a necessity but an opportunity for long-term growth and competitiveness. Using the Panel QARDL model, the findings reveal positive and negative relationships between these variables and emissions levels, which vary across different quantiles. Global innovation is shown to consistently reduce emissions across all levels, with an especially strong impact in higher-emitting countries. This suggests that advancements in sustainable technologies and practices can be particularly effective where emissions are concentrated, highlighting the importance of promoting innovation as a core strategy for reducing the MENA region's carbon footprint.

The MENA region stands at a pivotal moment where the integration of innovation, governance, finance and environmental quality can significantly enhance its path toward sustainable business practices and a low-carbon economy. More importantly, governance is associated with higher emissions, especially in countries with low and high emissions. This implies that stability alone, in the absence of proactive environmental policies, may not contribute to emissions reductions and could even allow emissions to increase. Therefore, environmental governance should be a key consideration in stable governments to ensure that economic and political stability supports environmental objectives. Additionally, financial development tends to increase emissions, with the exception of higher-emission countries in the long term. While no clear pattern emerges across most quantiles, reduced financial development is associated with notable emission reductions in the highest-emission countries. This suggests that limiting financial development could be particularly effective in these contexts by encouraging more transparent and accountable environmental practices.

Economic growth, on the other hand, consistently increases emissions, and this effect intensifies in higher-emitting countries. This result highlights the difficulty of balancing economic growth with environmental sustainability, especially in countries with already high emission levels. The results suggest that without careful policy adjustments, continued economic growth in the region may exacerbate carbon emissions, potentially counteracting efforts to achieve carbon neutrality. Green energy consumption is effective in reducing emissions, particularly in countries with moderate to high emissions. By expanding their use of renewables, MENA countries tap into their abundant natural resources to significantly decrease emissions while meeting energy demands.

In conclusion, long-run innovation and green energy play crucial roles in reducing emissions, while economic growth remains a challenge for environmental and business sustainability. Specifically, innovations in sustainable technologies, resource-efficient production, and clean energy practices play a crucial role in reducing carbon emissions. Additionally, enhancing environmental quality by reducing pollution levels, improving air and water quality, and promoting ecosystem health is shown to align closely with the region's carbon neutrality objectives. However, the effectiveness of these factors depends on the level of commitment by MENA countries to integrate global innovation and stringent environmental standards into national

policies. This study highlights that achieving for environmental and business sustainability in the MENA region requires not only the adoption of new technologies but also the establishment of frameworks to encourage sustainable practices across industries and communities.

The transition to carbon neutrality and business sustainability in the MENA region presents both a significant challenge and a unique opportunity. This study delves into the essential roles that global innovation, governance, and environmental quality play in shaping sustainable business practices. The findings emphasize the transformative potential of global innovations, particularly in green energy technologies, green financing, and resource-efficient solutions. Businesses in the MENA region can harness these innovations not only to reduce their carbon emissions and operational costs but also to gain a competitive edge in the expanding global green economy. By adopting cutting-edge technologies, companies can optimize their resource use, innovate processes, and align themselves with the increasing global demand for sustainability, ultimately securing their position in the future market. Moreover, governance has proven to be a key enabler of sustainability in the region. The study highlights that effective governance, through robust policies, regulations, and incentives, is crucial in guiding businesses toward carbon neutrality. Governments in the MENA region play a central role in fostering an environment where sustainability is prioritized. Also, strong governance frameworks, combined with transparent regulatory measures, create the conditions necessary for businesses to integrate sustainable practices into their operations. This is particularly important as businesses need clear, supportive policies to align with national and global climate goals, ensuring that their sustainability efforts are both meaningful and impactful.

At the same time, environmental quality is another critical aspect directly linked to business sustainability. This study underscores that improving environmental quality, through practices such as reducing carbon emissions, conserving resources, and managing waste, is not merely an environmental obligation but also a strategic business move. Enhancing environmental quality can lead to improved corporate reputations, increased consumer loyalty, and the opening of new revenue streams. As businesses adopt more sustainable practices, they can meet the rising consumer demand for eco-friendly products and services, while simultaneously positioning themselves as leaders in corporate responsibility. The shift toward sustainability is no longer optional but has become a driving force for long-term business success. However, significant obstacles remain for businesses in the MENA region, such as the heavy reliance on fossil fuels, limited access to green financing, and political instability. These barriers make it difficult for businesses to transition to low-carbon, sustainable models. Despite these challenges, the MENA region also holds tremendous potential for green growth, particularly in sectors like green energy, sustainable agriculture, and green technologies. By tapping into these sectors, businesses can not only contribute to the region's environmental goals but also benefit from the growing global shift toward sustainability.

These barriers underscore the need for coordinated efforts among governments, businesses, and international organizations. Collaborative initiatives are essential to overcoming these challenges and unlocking the vast opportunities presented by the green economy. It will require a unified approach that integrates policy reforms, innovative business practices, and investment in green technologies to fully capitalize on the potential for sustainable growth in the MENA region.

In light of these findings, several policy recommendations emerge. First, governments in the MENA region should strengthen regulatory frameworks and incentives for businesses pursuing sustainability. Policies that offer tax incentives, subsidies, and grants for green energy projects and carbon reduction initiatives will encourage companies to invest in greener technologies. Clear environmental standards and stringent enforcement mechanisms will also ensure that businesses comply with sustainability objectives and drive progress toward carbon neutrality.

Second, this study highlights the critical role of green financing in enabling businesses to transition to sustainable operations. Policymakers should prioritize expanding access to green financing mechanisms, such as green bonds and sustainable investment funds, to support companies in their green initiatives. Providing financial incentives and improving access to low-cost capital for environmentally responsible projects will reduce the financial barriers that often prevent businesses from implementing sustainable practices.

Furthermore, public-private partnerships should be fostered to promote innovation in sustainable technologies. Governments should create conducive environments for collaboration between businesses, research institutions, and policymakers, enabling the development of cutting-edge clean technologies. This

will accelerate the adoption of sustainable practices and create new opportunities for businesses to lead in global markets. Investments in green infrastructure, such as green energy grids, waste management systems, and energy-efficient buildings, should also be prioritized to lay the foundation for businesses to adopt sustainable practices with greater ease.

Another recommendation is the need to improve environmental quality standards and monitoring systems. Governments must set clear environmental benchmarks for businesses, while robust monitoring and reporting mechanisms will ensure accountability. Encouraging companies to reduce carbon emissions, manage waste efficiently, and conserve natural resources will be essential to improving the region's overall environmental quality. Additionally, corporate social responsibility (CSR) and environmental, social, and governance (ESG) reporting should be incentivized. Transparent ESG reporting will not only boost company accountability but also attract investors focused on sustainability.

Finally, the success of these initiatives requires regional and global collaboration. Governments should actively engage in international sustainability efforts, aligning local policies with global climate commitments. By participating in cross-border knowledge sharing, the MENA region can leverage global best practices and gain access to international sustainability networks, helping businesses in the region meet global environmental standards and expand into international markets.

Future research could delve deeper into the specific challenges faced by businesses in different sectors of the MENA economy, particularly in industries that are heavily dependent on fossil fuels, such as petrochemicals and transportation. Understanding the unique barriers and opportunities in these sectors would provide more granular insights into how carbon neutrality can be achieved across diverse industries in the region.

Governance also plays a critical role in fostering business sustainability, but the mechanisms through which governance structures can be improved remain an area for further research. Future studies could explore how different governance models, such as public-private partnerships and multi-stakeholder initiatives, contribute to driving sustainability in the region. Research could focus on the impact of policy coherence, the effectiveness of environmental regulations, and how businesses in the MENA region respond to government incentives aimed at reducing carbon emissions. In particular, examining the influence of political stability and regulatory enforcement on the adoption of sustainability practices could provide valuable insights into governance frameworks that best support long-term sustainability goals.

Another promising area for future research is the integration of sustainable business practices with corporate social responsibility (CSR) and environmental, social, and governance (ESG) metrics. As businesses increasingly incorporate ESG factors into their strategies, research could explore the relationship between CSR activities and long-term business performance in the MENA region. Specifically, studies could investigate how CSR initiatives contribute to building brand equity, enhancing stakeholder relations, and attracting sustainable investment. Additionally, research on the integration of ESG criteria into corporate governance and decision-making processes in the MENA region could help further understand the motivations and outcomes of businesses' sustainability efforts.

Another avenue for future studies is the role of green financing in accelerating business sustainability. While this study emphasizes the importance of green financing, there is a need for more empirical research on the effectiveness of various green financing mechanisms in the MENA context. Future studies could explore the barriers to access, the role of financial institutions, and the impact of government policies on the growth of green finance in the region. Additionally, research could examine the potential for innovative financing models, such as blended finance or sustainability-linked bonds, to support businesses in their transition to sustainability.

Additionally, future research could examine the role of public environmental awareness and education in supporting carbon neutrality initiatives. Also, these studies could explore how emerging technologies, such as artificial intelligence, blockchain, and IoT, might be integrated into environmental policies. Assessing how these technologies could improve emissions tracking, resource management, and policy enforcement would offer valuable guidance for digital innovation in environmental governance.

REFERENCES

Abdouli, M., & Hammami, S. (2017). The Impact of FDI Inflows and Environmental Quality on Economic Growth: An Empirical Study for the MENA Countries. *Journal of the Knowledge Economy*, 8(1), 254–278. https://doi.org/10.1007/s13132-015-0323-y

Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The Environment and Directed Technical Change. American Economic Review, 102(1), 131-166.

Albaker, A., Abbasi, K. R., Haddad, A. M., Radulescu, M., Manescu, C., & Bondac, G. T. (2023). Analyzing the Impact of Renewable Energy and Green Innovation on Carbon Emissions in the MENA Region. *Energies,* 16(16). https://doi.org/10.3390/en16166053

Al-Mulali, U., & Sab, C. N. B. C. (2012). The impact of energy consumption and CO2 emission on the economic and financial development in 19 selected countries. *Renewable and Sustainable Energy Reviews*, 16(1), 201-210.

Alnafisah, N., Alsmari, E., Alshehri, A., & Binsuwadan, J. (2024). Assessing the Impacts of Technological Innovation on Carbon Emissions in MENA Countries: Application of the Innovation Curve Theory. *Energies,* 17(4). https://doi.org/10.3390/en17040904

Alsayegh, M. F., Rahman, R. A., & Homayoun, S. (2020). Corporate economic, environmental, and social sustainability performance transformation through ESG disclosure. *Sustainability (Switzerland),* 12(9). https://doi.org/10.3390/su12093910

Alvarado, R., Tillaguango, B., Toledo, E., Murshed, M., & Işık, C. (2024). Links between technological innovation, financial efficiency and environmental quality using quantile regressions: The role of foreign direct investment, institutional quality and natural resources. *Journal of Open Innovation: Technology, Market, and Complexity*, 10(3). https://doi.org/10.1016/j.joitmc.2024.100360

Andriamahery, A., and Qamruzzaman, M. (2022). A Symmetry and Asymmetry Investigation of the Nexus Between Environmental Sustainability, Renewable Energy, Energy Innovation, and Trade: Evidence from Environmental Kuznets Curve Hypothesis in Selected MENA Countries. *Frontiers in Energy Research,* 9. https://doi.org/10.3389/fenrg.2021.778202

Awan, A. M., Azam, M., Saeed, I. U., & Bakhtyar, & B. (2020). Does globalization and financial sector development affect environmental quality? A panel data investigation for the Middle East and North African countries. *Environmental Science and Pollution Research,* 27, 45405–45418. https://doi.org/10.1007/s11356-020-10445-4/Published

Ayad, H., Sari-Hassoun, S. E., Usman, M., & Ahmad, P. (2023). The impact of economic uncertainty, economic growth and energy consumption on environmental degradation in MENA countries: Fresh insights from multiple thresholds NARDL approach. *Environmental Science and Pollution Research*, 30(1), 1806–1824. https://doi.org/10.1007/s11356-022-22256-w

Ben Cheikh, N., Ben Zaied, Y., & Chevallier, J. (2021). On the nonlinear relationship between energy use and CO2 emissions within an EKC framework: Evidence from panel smooth transition regression in the MENA region. *Research in International Business and Finance,* 55. https://doi.org/10.1016/j.ribaf.2020.101331

Block, S., Emerson, J. W., Esty, D. C., de Sherbinin, A., Wendling, Z. A., et al. (2024). 2024 Environmental Performance Index. New Haven, CT: *Yale Center for Environmental Law & Policy*. epi.yale.edu

Bölük, G., & Mert, M. (2014). The renewable energy, growth and environmental Kuznets curve in Turkey: An ARDL approach. *Renewable and Sustainable Energy Reviews*, 52, 587-595.

Charfeddine, L., & Kahia, M. (2019). Impact of renewable energy consumption and financial development on CO2 emissions and economic growth in the MENA region: A panel vector autoregressive (PVAR) analysis. *Renewable Energy*, 139, 198–213. https://doi.org/10.1016/j.renene.2019.01.010

Cho, J. S., Kim, T. H., & Shin, Y. (2015). Quantile cointegration in the autoregressive distributed-lag modeling framework. *Journal of Econometrics,* 188(1), 281–300. https://doi.org/10.1016/j.jeconom.2015.05.003

Costantini, V., Crespi, F., Marin, G., & Paglialunga, E. (2013). Environmental regulation and the export dynamics of energy technologies. *Journal of Environmental Economics and Management*, 66(1), 68-89.

Gaies, B., Nakhli, M. S., & Sahut, J.-M. (2022). What are the effects of economic globalization on CO2 emissions in MENA countries?. *Economic Modelling*, Elsevier, vol. 116(C). https://doi.org /10.1016/j.econmod.2022.106022.

Gang, C., Sha, H., & Qamruzzaman, M. (2023). Nexus between energy efficiency, green investment, urbanization and environmental quality: Evidence from MENA region. *PLoS ONE,* 18(12 December). https://doi.org/10.1371/journal.pone.0295628

Hao, Y., Wu, Y., Wu, H., & Ren, S. (2020). How do FDI and technical innovation affect environmental quality? Evidence from China. *Environmental Science and Pollution Research,* 27(8), 7835–7850. https://doi.org/10.1007/s11356-019-07411-0

IPCC (2018). Global warming of 1.5°C. Intergovernmental Panel on Climate Change.

IPCC. (2022). Overarching Frequently Asked Questions and Answers (Sixt Assessment Report: Impacts, Adaptation, and Vulnerability). 2022(February), 1.

Jin, G., & Huang, Z. (2024). Resource curse or resource boon? Appraising the mediating role of fin-tech in realizing natural resources-green growth nexus in MENA region. *Resources Policy,* 89. https://doi.org/10.1016/j.resourpol.2023.104590

JinRu, L., & Qamruzzaman, M. (2022). Nexus Between Environmental Innovation, Energy Efficiency, and Environmental Sustainability in G7: What is the Role of Institutional Quality? *Frontiers in Environmental Science,* 10. https://doi.org/10.3389/fenvs.2022.860244

Kahia, M., Kadria, M., Ben Aissa, M. S., & Lanouar, C. (2017). Modelling the treatment effect of renewable energy policies on economic growth: Evaluation from MENA countries. *Journal of Cleaner Production,* 149, 845–855. https://doi.org/10.1016/j.jclepro.2017.02.030

Khaled, M. W. Ben, Dahmani, M., & Ben Youssef, A. (2024). Overcoming Barriers to Energy Transition in the MENA Region: New Institutional Dynamics. https://doi.org/10.20944/preprints202402.1440.v1

Lilliestam, J., & Patt, A. (2015). Barriers, risks and policies for renewables in the Gulf States. *Energy Policy,* 76, 198-210.

Miketa, A., & Merven, B. (2013). Africa's renewable energy potential: Mapping resources and supporting infrastructure. *International Renewable Energy Agency*.

Mtiraoui, B. A., Lazreg, M., Chemli, L., & Mtiraoui, A. (2024). Institutional Quality and Economic Growth in the Energy Transition of MENA Countries. *International Journal of Energy Economics and Policy*, 14(6). https://doi.org/10.32479/ijeep.16230ï

Pedroni, P. (2004). Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric Theory,* 20(3), 597–625. https://doi.org/10.1017/S0266466604203073

Popp, D. (2019). Environmental policy and innovation: A decade of research. *Review of Environmental Economics and Policy,* 13(2), 209-228.

Said, R., & Acheampong, A. O. (2024). Achieving Carbon-Neutrality in MENA Countries: Does Financial Inclusion Matter? *Journal of Environment and Development,* 33(2), 312–336. https://doi.org/10.1177/10704965231225780

Said, R., & Acheampong, A. O. (2024). Achieving Carbon-Neutrality in MENA Countries: Does Financial Inclusion Matter? *Journal of Environment and Development,* 33(2), 312–336. https://doi.org/10.1177/10704965231225780

Saidi, K., & Omri, A. (2020). The impact of renewable energy on carbon emissions and economic growth in 15 major renewable energy-consuming countries. *Environmental Research,* 186. https://doi.org/10.1016/j.envres.2020.109567

World Bank. (2014). Turn Down the Heat: Confronting the New Climate Normal. World Bank Group.

Xian, X., Wu, J., Huang, M., & Mou, Q. (2024). Do green policies achieve the carbon neutrality target? Revealing the effectiveness of environmental innovation. *Natural Resources Forum*. https://doi.org/10.1111/1477-8947.12572

Xu, D., & Hussain, J. (2023). Globalization, institutions, and environmental quality in Middle East and North African countries. *Environmental Science and Pollution Research,* 30(26), 68951–68968. https://doi.org/10.1007/s11356-023-27348-9

Zhang, L., & Wei, W. (2017). The energy consumption, CO2 emissions, and economic growth nexus in MENA countries: Evidence from simultaneous equations model. *Energy Sources,* Part B: Economics, Planning, and Policy, 12(9), 802-808.

Zhou, D., Saeed, U. F., Kongkuah, M., & Wiredu, I. (2024). Examining the moderating role of environmental regulations on financial development and ecological footprint in the MENA region. *Environment, Development and Sustainability.* https://doi.org/10.1007/s10668-024-05430-7

Zinecker, M., Gass, P., Gerasimchuk, I., Jain, P., Moerenhout, T., Oharenko, Y., & Merrill, L. (2018). Real people, real change: Strategies for just energy transitions. *International Institute for Sustainable Development.*