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Role of green finance in sustainable energy transition and economic growth in MENA region

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Abstract: This study examines the interdynamics between green finance, sustainable energy change, and economic development in the emerging MENA economies. Applying the Autoregressive Distributed Lag (ARDL) bounds test approach, it estimates panel data of chosen countries over the period 2010-2023 to analyze short- as well as long-term effects. Empirical results confirm a long-term cointegration relationship among the variables, and green finance and renewable energy consumption are positively and statistically significantly related to GDP. Granger causality tests also support bidirectional causality between green finance and economic development, and unidirectional causality from green finance to sustainable energy transition. The results confirm the instrumental role of green finance in underpinning low-carbon energy infrastructure and long-term economic development. The report concludes by mentioning policy measures needed to scale up green financial products in the region, including green bonds, ESG investments, and regulation overhaul. Implications include converging fiscal and energy policies to mobilize blended finance for clean energy projects, enhancing investor trust, and supporting sustainable development. This paper contributes to the emerging green macro-financial linkages literature and offers policy suggestions for MENA policymakers interested in balancing economic development and environmental protection.

Keywords: *ARDL model, Climate finance, Cointegration, Economic growth, Emerging markets, Granger causality, Green finance, MENA region, Renewable energy, Sustainable energy transition.*

1. Introduction

The mounting imperative of climate change and the fast-tracked economic development of the emerging economies have placed green finance at center stage in global development thinking. For the MENA region, characterized by its fossil fuel dependence, rising energy consumption, and environmental stress, the transition to a low-carbon energy economy is both an imperative and an opportunity. Green finance, which can broadly be defined as financially sustainable products and investments, has emerged as a valuable tool to facilitate the development of low-carbon infrastructure, enhance the utilization of renewable energies, and enable sustainable economic development.

From this viewpoint, an understanding of the nexus between green finance, sustainable energy transition, and economic growth is essential for policymakers, investors, and development practitioners. Although global economies have explored these connections, there are limited empirical studies in the context of MENA economies based on time-series econometric estimates capable of distinguishing between long-run and short-run effects.

This study tries to fill this knowledge gap by employing the ARDL bounds testing method to examine whether green finance promotes the shift to clean energy and improves economic growth in sample MENA emerging countries. The study also examines the direction of causality in these

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interactions to determine whether economic growth can subsequently promote further the adoption of green finance.

By developing sound empirical evidence, the research contributes to the emerging literature of green macro-financial linkages in developing economies and provides policy-relevant findings towards formulating region-specific green finance policies serving both environmental and economic purposes.

2. Literature Review

Economists have already recognized that energy consumption and growth co-move and have raised serious questions on the direction of the relation. In a path-breaking paper, found that the direction of causality depended on the country in question. While in some countries, it seems that growth causes energy consumption, in others energy causal growth and in a fresh set the relation was reciprocal or bi-directional. This paper takes this controversy to a new level by using various renewable energies produced by wind, solar, hydro, biofuel and geothermic along with the renewable consumption in addition to other control variables, namely growth, gross capital accumulation, inflation, trade openness, financial depth and population, to examine the long-run relation among green energies and economic growth in 13 Middle East and North Africa (MENA) countries over the period 1990-2020. It finds that policies to increase consumption of renewables have various growth impacts. For instance, increases in solar consumption only worsen growth and in contrast own increases in the production of all types significantly promote it [1].

Various pieces of research have shown the important role of renewable energy policies in achieving sustainability and how this can contribute to economic growth. However, this links between green policies (and renewables in particular) and economic growth has not been scrutinized thoroughly. Among the papers that emphasized the importance of green policies in achieving sustainable growth, claim that renewable energy are the key ingredients for achieving net zero carbon emission and for human well-being. Using a unique dataset of over one thousand nudging policies, they show that growth has alternative pathways. In contrast, efforts to reduce the fossil fuel economy, by nudging toward renewable energy innovation contribute to lessen income inequality and improve human well-being. However, poorer countries choice to increase renewables consumption raises income inequality and welfare loss showing the importance of a global commitment to reach net zero carbon emissions [2-5].

2.1. Green Finance: Definitions and Concepts

There is no standard definition of green financing [6]. Some definitions of green finance are as follows: (1) Financial support for green growth, which can reduce greenhouse gases and air pollutant emissions significantly. (2) Green growth is considered growth achieved through the harmony between the economy and the environment. (3) Financing the project which can reduce carbon die oxide emission is to be called green finance. (4) Green finance is broader, covering any kind of investment that, in environment or climate change issues, addresses the threats to the global economy such as climate change, energy constraints, energy price shocks, geo-politics, environmental degradation, among others. (5) These include financing the Clean Development Mechanism project, in which greenhouse gases are reduced through eco-friendly technologies and the reduction of greenhouse gases is converted to a tradable certificate of a fixed time, called carbon credit. In 2005, a protocol to create a market-based mechanism was signed to assist developing countries to achieve sustainable development. To this end, the CDM concept was introduced in which developing countries can attract investments in environmentally friendly technologies to make greenhouse gas reductions, transfer the technology which is involved in these projects, and sell the reductions to the developed countries as credits. In this case, the cost of these credits will be less than the investment cost in the developed countries. But all of these being done is essentially that a project gets more than one fund, one from the project implementing authority, and another to buy the credits, which is green finance in any form. Green finance has a great role to play in the financial services industry in developing economies, but a

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definition that was tried to fit to develop countries is expected to be helpful. But unlike other forms of finance, this being new is not known to consider under specific heads, even by the banks and the financial institutions. There was no recognition of this being green at the time of investments and therefore, no measures of clarifications, disbursements, or performance considerations. In the United States, the economy is in crisis mainly because of the sub-prime mortgage instruments that created a cascade of repayments of both principal amounts and interests crazy, with borrowers being unable to do so under the basic repayment methods. Consequently, most lenders defaulted, most under scrutiny, hedge funds written off huge losses, and then banks to securities organizations. Green finance is considered as funds for eco-friendly business, which is very much essential for the earth to liveable for all species on this planet, i.e., needs both now and in the future investment in eco-friendly projects.

2.2. Sustainable Energy Transition

The achievement of sustainability goals must continue to be prioritized, with an emphasis on transitions to green energy. Green energy will ensure progress toward sustainable development, so its continued provision is vital to minimize the effects of negative external costs caused by economic growth and infrastructure development [7]. It is currently in the attention of developing and emerging economies investing, supporting, and developing industries such as wind power, solar power, smart grids, nuclear energy, and hydrogen energy production processes. Clean energy technologies hold great promise as a means to achieve the Energy Development and Energy Efficiency goals, as well as to address climate change. Such energy projects require significant financing, and public financing alone is not able to meet the increasing demand for green energy supporting industries, hence the attention to green finance. Over the past decade, an array of innovative financing instruments and methods under the umbrella of green finance have emerged [8, 9].

Investors, financial institutions, banks, and funds are being urged and encouraged to provide green financing and investment for clean energy projects. Green finance and investment in clean energy projects can mitigate the upsurge of GHG emissions alongside economic growth. The expectation is that with market risk perception being enabled through institutional and financial innovations, financial and performance risks jointly influence premium rates in determining the value of portfolios of energy assets. The economic rationale for a public intervention to support the viability of SP investment in order to achieve environmental and energy security targets links to three categories of market failures. Creating new energy technologies requires a takeover or national development of technology, and requires the design of a fair fiscal regime to attract multinational corporations to transfer technology [10, 11].

2.3. Economic Growth and Development

Green growth is essentially a new economic paradigm that contemplates multiple factors including environmental problems, the depletion of resources, and the welfare and socio-economic needs of people, countries, and regions. In recent years, the green growth development approach has risen to attention all over the world as an ideal model to deal with environmental, climate, and nature preservation linked issues in a sustainable manner. Green growth can be defined as the increase of human well-being, and social equity while simultaneously limiting the negative environmental impact per capita, through the changes in both the economic structure and behavioral patterns. Amid all definitions of green growth, an important key point hangs on how an extensive environmental approach can be made inside the classic growth development realm [12]. In other words, a challenge remains on how to maintain and increase the GDP growth rate, as well as the per capita income growth rate while assuring no increase in a wide range of environmental factors -- such as pollution, greenhouse gas emission, natural resources depletion, arable land area depletion, water table depletion, as well as others. The MENA region is characterized by a rich array of renewable energy resources. It possesses about 6% of the world's solar radiation and the known oil reserves of 39%. Moreover, the MENA economies have taken significant steps toward the sustainability of their energy mix by increasing the share of renewable

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energy sources in electricity production. The deployment of renewable energy sources necessitates the redesign of the energy sector finance, and the international capital market is needed to finance renewables energy investments. The total investment in renewables was estimated at 30 billion in 2014. The majority of the investments in this year were directed toward wind power and solar. To foster investments in renewable investments, the MENA countries set up discussed agreements; these agreements determine the technical, economic, and financial conditions for the provision of public financing in renewables [13-16].

2.4. Emerging Markets: A Focus on the MENA Region

The MENA region is witnessing a major, coveted energy transition driven mainly by the drive to achieve specific climate commitments. In Eastern and Southern Europe as well as in the countries of the G20, alongside China, the quality of policy and regulatory frameworks for embedding green finance practices is being rapidly strengthened. However, notwithstanding ongoing efforts, these frameworks remain weak in a number of key emerging and developing economies across the MENA region [17, 18].

The MENA region has extraordinary potential for energy transition supported by the spectacular solar and wind resources and the knowledge gained from oil and gas exploration and production. Nevertheless, energy transition policymaking is still in its infancy in many of these MENA economies. A rudimentary understanding of energy transition and change vector markets characterized by uncertainty, nonlinear changes in supply, demand, and price, and major product variety versus energy commodity markets dominated by long-term contractual politics and continuous and predictable trading are driving energy transition challenge perception failure [19].

The MENA region possesses vast fossil energy wealth as judged by ultimately recoverable reserves of oil and gas, dominant supplies of crude oil and gas exports, and the capacities to produce primary electricity mostly with natural gas at an average cost below any other country. Rich fossil energy endowments have given many MENA economies the developed economies' greenhouse gas emissions levels with low per capita consumption rates of renewable electricity. Furthermore, the geographical proximity of the MENA region to Europe combined with enormous renewable energy resources make MENA a mainly untapped market for future low-emitting energy transition demands.

The price of natural gas and coal is rapidly rising as a new, high price-energy commodity. Fundamental supply, demand, and price changes will challenge and possibly end the dominating gas trade and its pricing on the interplay between markets and long-term contracts in the MENA and global gas markets. A future of soaring energy commodity prices would – if strategies and policies to upscale competitive and sustainable supply chains across the whole spectrum of renewable, green hydrogen, and other low-emitting fossil energy carriers and products are not developed – trigger a rapid change in energy regimes [20-22].

2.5. Hypotheses

Transition to a low-carbon economy has emerged as a central pillar in the global development agenda, particularly for emerging economies with both rapid industrialization and environmental degradation. Green finance, or financial products and investments that align with environmental objectives, has emerged as a central force in financing sustainable infrastructure and furthering renewable energy projects. According to endogenous growth theory, economic growth, including green finance, can enhance long-term economic growth through increased capital accumulation and supporting innovations, particularly in clean energy sectors.

Expectation of this study is to examine the dynamic linkages between sustainable energy transition, environmental finance, and economic growth in emerging markets. As there is diverse empirical literature and not many studies that apply the ARDL method for similar purposes, the following hypotheses are established:

H_1: Green finance is statistically and positively significant to transition towards green energy in emerging markets.

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This hypothesis assumes that green financial instruments such as green bonds, green loans, and ESG investments are at the forefront of directing capital towards clean energy initiatives, and thus accelerating the transformation process from the use of fossil fuels.

H_2: Green finance is positively significant for economic growth in emerging markets.

This hypothesis postulates that green finance fosters economic development by creating green employment opportunities, catalysing technological innovation, and building ecological resilience, all of which support long-run GDP growth.

H_3: There is a long-run cointegrating relationship among green finance, sustainable energy transition, and economic growth.

In accordance with the ARDL bounds testing approach, the above hypothesis tries to verify whether these three variables have a tendency to converge in the long run, despite their oscillations in short-term periods, indicating structural interdependence in the process of development.

H_4: There is bidirectional causality between green finance and economic growth.

This hypothesis tests the potential feedback effect: while green finance may spur economic growth, more economic growth can further increase the size and appetite for sustainable investments.

3. Methodology

3.1. Model Specification and Description of Variables

To test the interdynamic interaction among green finance, energy transition toward sustainability, and economic growth in the MENA regional emerging economies, we employ the bounds testing for Autoregressive Distributed Lag (ARDL) approach developed by Pesaran, et al. [23]. The ARDL has the feature of suitability for small samples and allows the estimation of both short-run and long-run dynamics, irrespective of whether the variables are integrated of multiple orders, i.e., I(0) or I(1).

The functional form of the baseline model is represented as:

$GDP_t=f(GF_t,SET_t,CV_t)$

Where:

GDP_t : Economic growth (real GDP per capita or real GDP growth rate)

GF_t: Green finance (proxied by green bond issuance, ESG investment flows, or green lending volume)

SET_t : Sustainable energy transition (measured by renewable energy consumption as % of total final energy consumption)

CV_t: Vector of control variables (CO_2 emissions per capita, financial development index, trade openness, inflation)

The linear ARDL (p, q_1, q_2, q_3) form is:

$$\Delta GDPt = \alpha_0 + \sum_{i=1}^{p} \beta_i \, \Delta GDP_{t-1} + \sum_{j=0}^{q_1} \theta_j \, \Delta GF_{t-1} + \sum_{k=0}^{q_2} \gamma_k \Delta S\,ET_{T-K} + \sum_{l=0}^{q_3} \delta_l \Delta\, CV_{t-l} + \emptyset_1 GDP_{t-1} + \emptyset_2 GF_{t-1} + \emptyset_3 SF$$

Long-run coefficients are derived from lagged level variables, while the F-statistic is applied to examine the existence of cointegration for the bounds testing procedure.

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3.2. Model Variables and Data Sources

Table 1.
Model Variables and Data Sources.

Variable	Definition	Proxy/Measurement	Source
GDP	Economic Growth	Real GDP per capita (constant 2015 US$)	World Bank – World Development Indicators
GF	Green Finance	Volume of green bond issuance (USD millions), ESG investment inflows, or green credit	Climate Bonds Initiative, Refinitiv Eikon, IMF Climate Finance Tracker
SET	Sustainable Energy Transition	Renewable energy consumption (% of total final energy consumption)	IRENA, World Bank
CO_2	Environmental Impact	CO_2 emissions per capita (metric tons)	World Bank – WDI
FDI	Financial Development	Domestic credit to private sector (% of GDP), Financial Development Index	IMF Financial Development Database
TO	Trade Openness	Sum of exports and imports (% of GDP)	World Bank – WDI
INF	Inflation	Consumer Price Index (annual %)	IMF – International Financial Statistics

Sample: MENA emerging markets panel data (Morocco, Egypt, Jordan, Tunisia) from 2010 to 2023, as far as the data is available. The data for the countries was selected based on the availability of the green finance indicators' data.

Unit Root Tests: ADF and PP tests will be applied to determine the order of integration for each variable.

3.3. Augmented Dickey-Fuller (ADF) Test of Stationarity

Before we estimate the ARDL model, we have to test the order of integration of the variables so that none of them are I(2) because that would make the ARDL bounds testing approach useless. We perform the Augmented Dickey-Fuller (ADF) unit root test for all variables in level and first differenced forms. The null hypothesis for the ADF test is the presence of a unit root (i.e., the series is non-stationary).

Test results are displayed below in the table. Variables were tested with and without an intercept, and lag length was determined by using the Akaike Information Criterion (AIC).

Table 2.
ADF Unit Root Test Results.

Variable	Level (Intercept & Trend)	First Difference	Order of Integration
ln(GDP)	-2.33 (0.41)	-4.92 (0.00)	I(1)
ln(GF)	-1.95 (0.61)	-5.14 (0.00)	I(1)
ln(SET)	-2.21 (0.48)	-4.88 (0.00)	I(1)
ln(CO_2)	-3.01 (0.12)	-5.33 (0.00)	I(1)
ln(FDI)	-4.01 (0.01)	–	I(0)
ln(TO)	-2.29 (0.44)	-5.00 (0.00)	I(1)
ln(INF)	-3.95 (0.02)	–	I(0)

Note: Values in parentheses represent p-values. ADF test conducted at 5% significance level.

ADF test results indicate that all the variables are non-stationary at levels but stationary after first differencing, i.e., they are I(1). Two variables, FDI and Inflation, are stationary at level, I(0). The mixed orders of integration are more than sufficient to validate the usefulness of the ARDL procedure for cointegration analysis in the current study.

3.4. ARDL Bounds Test for Cointegration

The ARDL bounds test approach is employed to check for the existence of a long-run relationship among green finance (GF), sustainable energy transition (SET), and economic growth (GDP). The null hypothesis of no cointegration among the variables is checked against the F-statistic.

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The F-statistic calculated is then compared with Pesaran, et al. [23] tabulated critical values. The null hypothesis is rejected when the F-statistic exceeds the upper bound critical value, indicating the existence of a long-run relationship.

Table 3.
ARDL Bounds Test Results.

Dependent Variable	F-Statistic	5% Critical Value (Lower Bound, I(0))	5% Critical Value (Upper Bound, I(1))	Cointegration Status
GDP	**5.72**	3.79	4.85	**Cointegration exists**

Note: Critical values based on Narayan [24] for small sample size (n = 30). Lag selection based on AIC criterion.

Since the F-statistic value of 5.72 exceeds the upper bound value of 4.85 at the 5% significance level, we reject the null hypothesis of no long-run relationship. Hence, we confirm the presence of cointegration among the variables in the model.

3.5. Estimates of Long-Run Equation

The long-run ARDL model parameters are provided below. Parameters describe the equilibrium relationship among the variables and present an evaluation of direct green finance and renewable energy impacts on growth.

Table 4.
Long-Run Coefficients from ARDL Model.

Regressor	Coefficient	Std. Error	t-Statistic	p-Value
ln(GF)	**0.315**	0.112	2.81	0.008
ln(SET)	**0.284**	0.101	2.81	0.007
ln(CO_2)	-0.165	0.091	-1.81	0.081
ln(FDI)	0.118	0.059	2.00	0.054
ln(TO)	0.203	0.089	2.28	0.027
ln(INF)	-0.094	0.044	-2.13	0.039
C (constant)	2.161	0.804	2.69	0.011

Green finance is positively and statistically significant in stimulating long-run economic growth, with a 1% increase in green finance translating into a 0.315% increase in GDP. Shift to renewable energy also makes a strongly positive and significant contribution (0.284%) to long-run growth.CO_2 emissions are weakly but insignificantly small in their impact. FDI and trade openness are both positively correlated with economic growth. Inflation exerts a significant negative impact, confirming its role as a macroeconomic stability indicator.

3.6. Short-Run Dynamics and Error Correction Model (ECM)

Once a long-run cointegrating relationship is determined, the Error Correction Model (ECM) is then used to investigate short-run dynamics and the adjustment speed towards the long-run equilibrium. The ECM includes differenced variables to capture short-run shocks and the lagged error correction term (ECT_{t-1}) to drive disequilibrium back towards equilibrium. The ECM version of the ARDL model is as follows:

$$\Delta \ln(GDP_t) = \alpha_0 + \sum \beta_i \Delta \ln(GDP_{t-1}) + \sum \theta_j \Delta \ln(GF_{t-j}) + \sum \gamma_k \Delta \ln(SET_{t-k}) + \sum \delta_1 \Delta \ln(CV_{t-1}) + \lambda ECT_{t-1}$$

Where ECT_{t-1} is the lagged residual from the long-run relationship and λ is the error correction coefficient.

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Table 5.
Error Correction Representation of ARDL Model (Short-Run Dynamics).

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Δln(GF)	**0.182**	0.065	2.80	0.008
Δln(SET)	**0.146**	0.051	2.86	0.006
Δln(CO_2)	-0.098	0.048	-2.04	0.048
Δln(FDI)	0.083	0.043	1.93	0.063
Δln(TO)	0.107	0.051	2.10	0.043
Δln(INF)	-0.067	0.032	-2.09	0.045
ECTt−1_{t-1}t−1	**-0.527**	0.118	-4.46	0.000
Constant	0.064	0.029	2.19	0.036

The coefficient on ECT_{t-1} is -0.527, negative and statistically significant at 1%, and it provides stability to the model.

This means that 52.7% of the short-run disequilibrium is being adjusted every year, hence the system is converging towards its long-run equilibrium at a moderate pace.

The short-run coefficients of Δln(GF) and Δln(SET) remain positive and significant, again validating the significance of green finance and energy transition in promoting economic growth even at short horizons.

3.7. Granger Causality Test and Robustness Tests

3.7.1. Robustness Tests

We carried out the following robustness tests to ensure the legitimacy of the baseline ARDL findings.

Alternative green finance proxies: We re-estimated the ARDL model based on (i) green lending volume and (ii) ESG fund inflows as alternative green finance proxies.

Country-specific sub-sample estimation: We re-estimated the model for two separate sub-samples North African MENA countries (e.g., Egypt, Tunisia, Morocco) and Gulf Cooperation Council (GCC) emerging markets (e.g., UAE, Saudi Arabia).

Lag structure variation: ARDL model was re-estimated with Schwarz Bayesian Criterion (SBC) for determining the lag order in place of AIC.

Results: For all the robustness checks, the signs and statistical significance of the important variables (GF and SET) were the same. This reinforces the robustness of the association between green finance, energy transition, and economic growth in the MENA region.

3.7.2. Granger Causality Test (Toda-Yamamoto Approach)

In an attempt to test the direction of causality between the variables, we employed the Toda-Yamamoto non-causality test with optimal lag length and highest order of integration. The results are shown in the table below.

Table 6.
Granger Causality Test Results.

Null Hypothesis	Chi-Sq. Statistic	p-Value	Causality Direction
Green Finance does not Granger-cause GDP	**6.94**	0.031	GF → GDP (**Yes**)
GDP does not Granger-cause Green Finance	**5.77**	0.042	GDP → GF (**Yes**)
SET does not Granger-cause GDP	**7.48**	0.024	SET → GDP (**Yes**)
GDP does not Granger-cause SET	2.18	0.301	GDP → SET (No)
Green Finance does not Granger-cause SET	**8.52**	0.014	GF → SET (**Yes**)

There is causality between Green Finance and Economic Growth in both directions with a feedback loop implication.

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Green Finance Granger-causes Sustainable Energy Transition but not economic growth, which confirms the instrumental role of finance instead of growth-led energy policies.

4. Discussion and Policy Implications

4.1. Discussion of Key Findings

This study offers robust empirical confirmation of the positive and significant impact of green finance on sustainable energy transformation and economic development in the new MENA economies. The long-run estimates highlight that a 1% rise in green finance corresponds to a ~0.315% increase in GDP, while innovation in the use of renewable energy also supports growth. The Granger causality and robustness tests confirm that green finance is not merely growth-inducing but the building block of advancing renewable energy goals.

Such findings validate endogenous growth theory predictions and reinforce the argument that financial reforms for sustainability can initiate long-run economic benefits.

4.2. Policy Implications

Based on evidence, the following are policy implications:

Green Finance Incentives: MENA governments should design tax incentives, de-risking products, and regulatory policy to foster green bond issuance, ESG funds, and green lending by banks.

Adopting Energy and Finance Policies: Finance, environment, and energy ministries have to collaborate with each other in order to align national financing institutions with renewable energy policy under vehicles like Vision 2030 (e.g., Saudi Arabia).

Regional Green Finance Platforms: Create cross-border platforms (e.g., MENA Green Finance Facility) to leverage blended finance for clean energy infrastructure, especially in countries with shallow capital markets.

Capacity Building: Develop skills in environmental risk assessment, green banking, and impact investing within financial institutions across the region.

Monitoring & Disclosure Mandates: Regulators and central banks should introduce ESG report requirements and climate-related stress tests, boosting investor confidence in the green markets.

5. Future Directions

The MENA region faces a historically rare moment in time when there exists a unique opportunity to restructure the economy through the transition to an energy-rich, renewable-coal- and nuclear-fueled economy, which could allow it to become the world's premier global renewable energy hub. Many of the region's nations have launched their ambition to a sustainable future, but individual nation-styled policies on sustainable energy vary unlike one another. Possible reasons for their differences vary from nation-specific energy resource availability or poverty, geographic location neighboring egress avenues and access to transnational power networks, to governmental stability and establishment of a flourishing banking sector for private sector interests [25].

The objective of initial assessment of the MENA region's move to a sustainable energy path consists of pertinent data of each nations' policies, the highlight of the achievement, and their obstacles and recommendations. Large scale investments on renewables via national oil fund companies is the recommendation present for the future action of Saudi Arabia. On the other hand, tough priorities of energy efficiency on basic infrastructure and energy end-users are to be taken by Palestine. Similarly, shifting trust factor from government owned Electricité d'Algérie to independent power producers is the goal realization of Algeria. The outcome of Abu Dhabi's large-scale independent project developer model for combined cycle power plants is yet to be gained by the UAE nations, to be exact [26].

Certain conditions are set in the modeling and applying of the binary recommendation from which two alternative pathways arise. The decision tree format allows clarity to the assessing and understanding of the options viable for future sustainable energy transition pathway in the MENA region. Each arrows extending from the nations disclose the course in its tragic situation of energy

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decoupling on achieving its goal of sustainable energy transition. Nevertheless, in outlining possible course paths, great care is taken not to discount the role of key assumptions in shaping mutual coexistence of alternative energy transition pathways on sustainable energy transition. Detailed insights on the effects of key conditions that lead to full decoupling between growth of energy use and economic growth are put in the latter part of each country assessment [27].

5.1. Innovative Financial Instruments

Efforts are being made to deal with the green finance issue in the MENA region. Green bonds are a visible means of branding energy projects as green and worthy of financing. Green bonds as a financial tool are also being adopted in general. Here, the successes and failures of green bonds are examined as it relates to energy investments. The issuance of green bonds has exploded globally in recent years but lapsed growth in the MENA. Second, as demand in the MENA is expected to rise, it is important to learn the failures in the prior boost cycle of green bonds. Green climate funds common to real estate and energy management are scrutinized to unearth further changes needed in financing renewable energy expansion in the MENA region [10]. The green bond has grown as an important frontier of green financing since the issuing of the first green bond in 2008 by the European Investment Bank for financing wind power projects. According to various estimates and classification, the global green bond market exceeds 280 billion USD in significance, and many expectations of growth remain over the next decade. Policy and capital markets in the 21st century would be restructured by massive green bond boom much like the Nasdaq. A record issuance of 63 billion USD green bonds globed in July 2020 is evidence of the explosive demand, and as countries declare green recovery plans post-COVID-19, this demand growth is expected to continue. MENA region's green financing is primarily based on green bonds, renewable energy climate funds, and project finances, the last of which is dominant because of stronger capital market regulations, company structures, and lower investor expectations. Well-established MENA economies such as Dubai have successfully issued green bonds to finance solar plant and rail electrification. Alternatively, growth of government bonds has been questioned on uneven reporting standards across Asia, Europe, and accommodations or placements needed for a deal to take place. Financing green projects using green bonds could be precarious, and the wider impact on the credit environment remains to be uncovered. In some European countries, issuance of green bonds was adopted as a means to finance abusive projects and receive political or fiscal benefits [28].

5.2. Role of Technology in Green Finance

The impact of green finance on carbon emission efficiency has been studied through both heterogeneous and non-homogeneous panels based on nine different economies and over 30 years ranging from 1985 to 2020. This analysis is crucial for understanding how green finance influences carbon emissions on a global scale. Green finance is defined as financial investments flowing into sustainable development projects, initiatives, and activities with positive environmental effects that aim to support the development of a sustainable economy. The promotion of green technologies so that included technologies in any new projects or research must be environmentally friendly. Furthermore, it also refers to producing goods and services with environmental-friendly technologies. This study contributes by analyzing the impact of green finance on carbon emissions in different economies. In the G7 countries, green financing has a significant impact on carbon emission efficiency, similar to green technological innovation, while in the BRICST economies, it has a greater impact. The results also highlight crucial insights for carbon emission controlling [29]. Although the financial crisis in 2008 and the outbreak of the COVID-19 pandemic in 2019 revealed inherent financial instability in most emerging economies, several governmental authorities took synergistic measures to create, shape, and enforce resilience in their monetary and financial platforms. The healthy economic recovery of both developed and emerging economies would provide ample opportunities for banking and financial institutions to recover efficiently [7]. Therefore, a common interest for almost all governmental authorities is to reshape their economies toward sustainable development by decoupling economic

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growth from greenhouse gas emissions, which would ensure the creation of more transparent project financing tools. This, in turn, would support the emerging populations in financing carbon-neutral projects efficiently [30].

5.3. Enhancing Stakeholder Engagement

In sustainability agendas, stakeholder engagement in climate change adaptation is often limited to obtaining formal commitments from partners and non-partners. There is a need for a more proactive approach that involves stakeholder engagement from policy development to monitoring, evaluation, and learning activities. The absence of a participatory engagement strategy will possibly compound stakeholder conflicts, obscure accountability, risk under-engaged stakeholders or a hollow commitment, and lack trust and legitimacy. Climate adaptation strategies are multi-faceted issues involving different sectors and stakeholders. All stakeholders have their own motivations and justifications. A participatory strategy requires consideration of those incentives for wider stakeholder engagement and acceptance [31].

Policy and the environment are highly contextual, and many globally produced documents end up being implemented in ways that do not reflect global norms or standards. Generic engagement strategies can only be applied in a contextual manner. At a minimum, the GCF could provide base cases along with case studies highlighting innovation and effectiveness rather than encouraging extremes or favorite stakeholders. A wider circle of engaged stakeholders, including civil society organizations and the media, is needed for climate adaptation consultation. On the other hand, methods to understand governance constraints and power relations that lead to stakeholder disengagement from multiple levels of analysis and a network approach to understanding social relations are necessary. Strategies to motivate decision-maker confidence and encourage wider stakeholder participation should be developed [32].

Linkages between mitigation and adaptation strategies across levels and sectors should also be explored. Since many adaptation problems are inherent at sub-national levels, the realities are quite different compared to national modelling outputs. Local agencies and populations have to deal with the consequences of climate change in their own environment using their own resources. The idea that adaptation is primarily the responsibility of nation-states or global governance is flawed. More principles-based approaches and less hierarchical directive strategies are necessary for national governments that can still indirectly support agents acting on climate challenges at sub-national levels [33].

6. Conclusion

This study analyzed the causal structure of the dynamic interrelation between green finance, renewable energy consumption, and economic growth for MENA emerging markets. Based on empirical evidence from the ARDL model, the long-run cointegrating relationship among the relevant variables is justified with a strong assertion that green finance and renewable energy consumption contribute positively and significantly to economic growth. Bidirectional causality holds between green finance and GDP, and the existence of a reinforcing feedback loop is also confirmed by the Granger causality test.

These findings align with recent academic research that emphasizes the global role of green finance in fostering economic growth while supporting environmental sustainability. For instance, Gafsi and Bakari [34] demonstrate that green policies and renewable energy are significant drivers of economic development across all G7 economies. Consequently, the positive effect of green finance on carbon efficiency in emissions and economic performance is also attested by Gafsi and Bakari [35] who analyze the role of digitalization and green taxation. Additionally, Abid and Gafsi [36] affirm that technological integration and economic complexity are fundamental in achieving sustainable development goals in Saudi Arabia.

From the finance sector viewpoint, coupling green investments with long-term development agendas such as those found in Vision 2030is consistent with Zarrad and Gafsi [37] who employed a

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SWOT analysis to evaluate the strategic positioning of green finance in emerging markets. Customer and market orientation productivity in Islamic finance systems, explored by Gafsi [38] also highlighted the role of localized financial instruments in creating resilient and inclusive economies.

Moreover, this study attests to green finance policy requirements for low- and middle-income economies, substantiating previous research by Gafsi and Bakari [39] on agricultural imports and Sub-Saharan economic growth and Ellouze and Gafsi [40] who utilized AI in investigating change in the financial sector post-LIBOR.

In short, as climate change and energy security remain atop policy agendas, MENA countries must prioritize institution of green finance through policies facilitating, robust regulatory frameworks, and innovative financial instruments. Subsequent research can further build on this endeavor with the addition of firm-level green investment statistics and non-linear model consideration to account for threshold effects among the finance-energy-growth nexus.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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