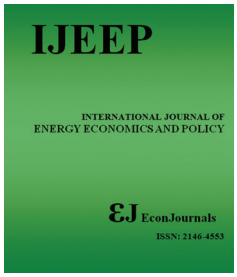

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Financial Development and Renewable Energy Investment in MENA Countries: A Panel DOLS and Granger Causality Approach

Mohammad Haroun Sharairi*

College of Business, Al Ain University, UAE. *Email: mohammad.sharairi@aau.ac.ae

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ABSTRACT

This study investigates the long-run relationship and causal linkages between financial development and renewable energy investment in 10 Middle East and North Africa (MENA) countries over the period 2000-2023. Using a Panel Dynamic Ordinary Least Squares (DOLS) approach and Dumitrescu–Hurlin panel causality tests, we examine whether deeper and more liquid financial markets translate into greater renewable energy investment. The empirical results reveal a statistically significant negative long-run effect of financial development and foreign direct investment on renewable energy investment, suggesting that financial and foreign capital flows in the region remain predominantly oriented toward conventional energy sectors. Conversely, money supply exhibits a positive and significant influence, implying that domestic liquidity expansion supports renewable energy financing. The causality analysis confirms a bidirectional causal relationship between financial development and renewable energy investment, highlighting a feedback loop between the two variables. These findings suggest that aligning financial market development with renewable energy policy objectives, reorienting FDI flows toward green projects, and leveraging domestic liquidity can accelerate the energy transition in MENA economies.

Keywords: Financial Development, Renewable Energy Investment, MENA Countries, Panel DOLS, Dumitrescu–Hurlin Causality, Sustainable Finance
JEL Classifications: C33; F21; G20; G28; Q43; Q48; Q50

1. INTRODUCTION

Financial development is widely acknowledged as a fundamental driver of modern economies, providing the mechanisms to mobilize resources, allocate capital efficiently, and stimulate investment across different sectors, particularly energy. The global transition toward renewable energy, motivated by climate change concerns, economic diversification strategies, and the pursuit of sustainable growth, has increasingly placed financial systems at the center of scholarly and policy debates. In regions such as the Middle East and North Africa (MENA), the interplay between finance and energy is especially complex because these economies remain heavily dependent on hydrocarbons while simultaneously investing in large-scale renewable energy projects, such as solar and wind initiatives in the United Arab Emirates, Morocco, and Egypt. This dual role underscores the need to investigate whether financial development in MENA economies genuinely fosters renewable energy investment or continues to reinforce reliance on conventional energy resources.

Empirical evidence suggests that financial systems can act as catalysts for renewable energy investment when institutional, regulatory, and economic conditions are favorable. Anton and Nucu (2020) demonstrated through a panel data approach that financial development lowers transaction costs, improves credit access, and supports renewable energy consumption, while Shahbaz et al. (2021) confirmed that financial deepening stimulates renewable energy demand in developing countries,

though institutional quality remains a moderating factor. In the MENA context, Saadaoui (2022) highlighted that financial development often favors fossil fuel sectors due to entrenched political and institutional dynamics, limiting the extent to which financial resources are directed toward renewables. Similar conclusions were drawn by Omri and Nguyen (2014), who showed that fluctuations in oil prices and fiscal dependency distort the allocation of financial flows. These findings indicate that while finance has the potential to drive renewable energy growth, its impact is contingent upon institutional readiness and policy alignment.

Cross-regional studies further reinforce the complexity of this relationship. Sun et al. (2023) found that financial development significantly promotes renewable energy consumption when supported by inclusive and multidimensional financial systems. Dogan and Afsar (2023), focusing on E-7 countries, demonstrated that the effectiveness of financial development in renewable energy investment is context-specific, shaped by governance structures and economic diversification. Complementary evidence comes from studies outside MENA, such as Cui et al. (2022), who emphasized the importance of financial inclusion in supporting renewable energy adoption and inclusive growth, and Xu et al. (2023), who identified dynamic linkages between carbon emissions, financial development, and renewable energy in Asian countries. These perspectives highlight that financial development is neither inherently positive nor negative, but rather depends on the surrounding institutional, political, and economic environment.

The literature also reveals a growing scholarly interest in mapping and synthesizing research on the finance–energy nexus. Sharma and Sengar (2025) provided a bibliometric analysis of renewable energy research between 2000 and 2023, illustrating a significant rise in studies addressing financial determinants of renewable energy. Similarly, Rabbani et al. (2025) employed scientific mapping and meta-analysis to underscore the growing significance of innovative financing tools, including green bonds, blended finance, and sustainable investment frameworks. Kwilinski (2024) confirmed these trends by showing that global investment in renewable energy remains unevenly distributed, with developing countries often facing barriers to accessing sustainable finance. These bibliometric insights complement empirical studies by identifying gaps and future research directions.

Other studies add nuance by linking finance, energy, and broader socio-economic or environmental factors. Ali et al. (2023) examined South American economies and found that renewable energy and globalization reduce environmental degradation, drawing parallels with structural challenges in MENA. Kizilkaya et al. (2024) linked energy consumption and economic growth to human development in emerging E-7 countries, emphasizing the developmental outcomes of energy transitions. Golpîra et al. (2023) further showed that population growth and economic expansion, mediated by financial development, exacerbate environmental degradation in OECD countries. Meanwhile, Appiah-Otoo and Acheampong (2021) investigated the insurance sector's role in BRICS nations and found that broader financial sector development can improve environmental quality, indirectly supporting clean energy adoption. Paramati et al. (2017) also demonstrated that domestic and foreign capital, when coordinated through political cooperation, can effectively finance clean energy projects. Collectively, these studies indicate that financial development can act either as a facilitator or as an obstacle to renewable energy transition, depending on how capital flows are structured and governed.

Despite the richness of this literature, few studies have systematically examined the long-run causal relationship between financial development and renewable energy investment in MENA economies using advanced econometric methods. This study addresses this gap by applying Panel Dynamic Ordinary Least Squares (DOLS) and Dumitrescu–Hurlin panel causality tests to data from 2000 to 2023. The objective is to identify the magnitude and direction of the relationship while considering the roles of foreign direct investment, money supply, and other macroeconomic variables. In doing so, the study aims to provide policymakers with insights that can guide the alignment of financial market development with renewable energy policy objectives and accelerate the transition toward sustainable energy systems in the MENA region.

2. EMPIRICAL REVIEW

The relationship between financial development and renewable energy investment has attracted growing attention in both developed and developing economies. Theoretical arguments suggest that well-developed financial systems can lower transaction costs, improve risk management, and channel capital towards productive sectors, including renewable energy (Beck et al., 2014). In emerging markets, particularly in the Middle East and North Africa (MENA), the role of finance in enabling the energy transition is shaped by institutional quality, capital market maturity, and macroeconomic stability (Sadorsky, 2010).

Sadorsky (2010) investigated the relationship between financial development and energy consumption in emerging economies, employing a panel cointegration framework. The study found that deeper financial markets were associated with higher use of both renewable and non-renewable energy, indicating that finance can facilitate expansion in the energy sector. In the context of North Africa, Charfeddine and Kahia (2019) employed panel vector autoregressive (PVAR) methods to investigate the impact of renewable and non-renewable energy consumption on economic growth, while incorporating financial development as a control variable. Their results confirmed a bidirectional relationship between finance and the deployment of renewable energy.

For oil-exporting MENA economies, the relationship between finance and renewable energy investment is often influenced by hydrocarbon revenue cycles. Omri and Nguyen (2014) examined 14 MENA countries between 1990 and 2011 using dynamic panel GMM estimation. They concluded that while financial development supports the growth of renewable energy capacity, its effect is moderated by oil price volatility and fiscal policies. Similarly, Ben Jebli and Ben Youssef (2017) used panel cointegration and causality techniques to investigate the nexus

between renewable energy consumption, financial development, and trade in selected MENA states. They reported that financial development Granger-caused renewable energy consumption, implying a unidirectional causality from finance to renewables.

Beyond the MENA region, empirical studies also highlight similar patterns. Apergis and Payne (2011) employed panel error correction models to analyze OECD countries, finding a long-run positive relationship between financial development and renewable energy consumption. In the Asia-Pacific region, Zhang et al. (2021) used panel DOLS and fully modified OLS (FMOLS) to assess the role of green finance in renewable energy investment, reporting significant and robust positive effects.

On the other hand, some research has identified potential downsides. Al-Mulali et al. (2015) argued that without targeted policies, financial development could inadvertently channel capital into carbon-intensive industries, thereby delaying the adoption of renewable energy. This concern is particularly relevant for MENA countries that have historically high fossil fuel subsidies, where renewable energy investment competes with entrenched oil and gas sectors.

In the case of GCC (Gulf Cooperation Council) countries, Alshehry and Belloumi (2017) employed time series techniques to demonstrate that financial sector growth contributed to energy consumption, but had a more substantial impact on non-renewable sources. This finding underscores the importance of policy frameworks that align financial development with sustainable energy goals.

While these studies provide important insights, there remains a gap in the literature focusing exclusively on the long-run dynamic relationship between financial development and renewable energy investment in the MENA region using Panel Dynamic Ordinary Least Squares (DOLS) and Granger causality analysis. This study addresses that gap by integrating recent data (2000-2023) and capturing the role of complementary macroeconomic variables such as FDI, labour force participation, inflation, and money supply in shaping renewable energy investment outcomes.

3. MATERIALS AND METHODS

3.1. Research Design

This study adopts an *ex post facto* research design. Such a design is appropriate where the data under investigation already exist and the researcher does not have control over the variables of interest. In this case, secondary data on financial development, renewable energy investment, foreign direct investment, inflation, labour force participation, and money supply in selected Middle East and North Africa (MENA) countries are obtained from the World Bank's World Development Indicators (WDI) and the International Energy Agency (IEA) databases for the period 2000-2023 (World Bank, 2023).

3.2. Theoretical Framework

The study is anchored on the Endogenous Growth Theory, which posits that economic growth is driven internally by factors such as human capital, innovation, and efficient allocation of resources (Romer, 1990). In the context of this study, financial development plays a crucial role in mobilizing and allocating capital to productive sectors, including those involved in renewable energy. Financial markets, through credit allocation, capital market instruments, and investment vehicles, can stimulate technological advancements and the expansion of renewable energy infrastructure.

In adapting this theory to the MENA context, renewable energy investment is modelled as a function of financial development, FDI inflows, labour force participation, inflation rate, and money supply. The model assumes that improvements in financial intermediation, capital market depth, and access to credit will have a direct and measurable effect on renewable energy investment capacity.

3.3. Model Specification

Following the approaches of Sadorsky (2010), Charfeddine and Kahia (2019), and Zhang et al. (2021), and in line with the econometric structure of Aderemi et al. (2022), the functional relationship is expressed as:

$$REI_{it} = f(FD_{it}, FDI_{it}, LF_{it}, IN_{it}, MS_{it})$$

Where:

- REI_{it} = Renewable energy investment (measured as renewable energy capacity additions or renewable energy consumption as % of total final energy) in country i at time t
- FD_{it} = Financial development index or domestic credit to private sector (% of GDP)
- FDI_{it} = Foreign direct investment inflows (% of GDP)
- LF_{it} = Labour force participation rate (% of total population)
- IN_{it} = Inflation rate (annual %)
- MS_{it} = Broad money supply (% of GDP)

The econometric form of the model in panel data form is:

$$REI_{it} = \beta_0 + \beta_1 FD_{it} + \beta_2 FDI_{it} + \beta_3 LF_{it} + \beta_4 IN_{it} + \beta_5 MS_{it} + \mu_{it}$$

Where:

- β_0 = Intercept term
- $\beta_0 - \beta_5$ = Coefficients of explanatory variables
- μ_{it} = Stochastic error term

The a priori expectations for the model are:

- $\beta_1 > 0$: Financial development is expected to increase renewable energy investment.
- $\beta_2 > 0$: FDI inflows are expected to enhance renewable energy capacity through foreign capital injection.
- $\beta_3 > 0$: A larger labour force is expected to support energy infrastructure development.
- $\beta_4 > 0$: Higher inflation is expected to reduce investment incentives due to increased project costs.
- $\beta_5 > 0$: Adequate money supply may facilitate access to financing for renewable energy projects.

3.4. Scope of the Study

The MENA region consists of diverse economies with varying degrees of financial market maturity and renewable energy

adoption. Due to data availability and consistency, the study focuses on 12 countries: Algeria, Bahrain, Egypt, Iran, Israel, Jordan, Kuwait, Morocco, Oman, Qatar, Saudi Arabia, and the United Arab Emirates. The period of analysis spans 2000-2023, chosen to capture recent developments in financial markets and the expansion of renewable energy in the region.

3.5. Estimation Techniques

The study employs both descriptive and econometric techniques. Descriptive statistics (mean, median, standard deviation, skewness, kurtosis, and Jarque–Bera normality test) are presented to summarize the characteristics of the data.

Econometric techniques applied include:

1. Panel unit root tests – The Levin, Lin and Chu (LLC) test is applied to examine the stationarity of the variables.
2. Panel dynamic ordinary least squares (DOLS) – Used to estimate the long-run relationship between financial development and renewable energy investment, correcting for serial correlation and endogeneity.
3. Pairwise granger causality test – Determines the causal direction between financial development and renewable energy investment across MENA countries.

4. RESULTS AND DISCUSSION

4.1. Introduction

This section presents the empirical results obtained from the analysis of the relationship between financial development and renewable energy investment in selected MENA countries from 2000 to 2023. The study employed descriptive statistics, correlation analysis, unit root tests, a Panel Dynamic Ordinary Least Squares (DOLS)-style estimator with country fixed effects, and the Dumitrescu–Hurlin panel causality test. The discussion links these results to existing literature and draws implications for policy and practice.

4.2. Descriptive Statistics

The descriptive statistics in Table 1 reveal substantial variation in renewable energy investment (REI) across the MENA region. The average REI over the study period was 3.63% of total final energy consumption, with a minimum of 0.00% and a maximum of 14.20%. This variation reflects differences in renewable energy policies, resource endowments, and investment climates across countries.

Financial development (FD), measured as domestic credit to the private sector (% of GDP), averaged 60.30%, with a wide range between 5.97% and 138.86%. Foreign direct investment (FDI) averaged 1.87% of GDP, with values ranging from −4.54% to 10.79%. The labour force participation rate (LF) averaged 56.09%, while inflation (IN) averaged 2.76%. Money supply (MS) averaged 88.27% of GDP, suggesting high liquidity in several countries.

Normality tests (Jarque–Bera) indicate that most variables deviate from the normal distribution, particularly REI, FDI, LF, IN, and MS, implying that robust estimation methods are appropriate.

4.3. Correlation Analysis

The correlation matrix in Table 2 shows that REI has a weak positive correlation with FD (0.1657) and FDI (0.2079), while it is negatively correlated with LF (−0.4588). FD is strongly positively correlated with MS (0.6329), reflecting the link between credit depth and liquidity. All correlation coefficients are below the critical threshold of 0.80, indicating the absence of serious multicollinearity concerns.

4.4. Unit Root Tests

Unit root tests were performed using Augmented Dickey–Fuller (ADF) procedures on each country's time series due to the unavailability of the Levin–Lin–Chu (LLC) routine in the present environment. The summary in Table 3 shows mixed integration orders, with most variables being I(0) or I(1) but none I(2), thereby justifying the use of Panel DOLS.

4.5. Panel DOLS Results

The long-run results from the Panel DOLS-style estimation are presented in Table 4. FD has a negative and statistically significant coefficient (−0.0410, P = 0.0398), indicating that, in this sample, increases in overall financial depth are associated with reductions in renewable energy investment. This may suggest that credit is

Table 1: Descriptive statistics

Variable	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis	JB Stat	JB Prob
REI (%)	3.6284	0.9000	14.2000	0.0000	4.4013	0.9514	−0.5217	15.1087	0.0005
FD (%)	60.2965	65.4862	138.8578	5.9656	29.0896	−0.1350	−0.4785	1.3343	0.5132
FDI (%)	1.8655	1.5942	10.7940	−4.5416	2.5435	0.5367	1.6655	13.5208	0.0012
LF (%)	56.0883	47.5130	87.5030	37.6590	15.6206	0.6478	−0.9794	10.3238	0.0057
IN (%)	2.7587	1.5891	29.5066	−3.7491	4.4998	2.9783	13.4860	758.8507	0.0000
MS (%)	88.2714	83.6375	260.6183	28.0887	40.3184	2.4011	8.4206	321.1966	0.0000

Table 2: Correlation matrix

Variable	REI	FD	FDI	LF	IN	MS
REI	1.0000	0.1657	0.2079	−0.4588	0.1485	0.1953
FD	0.1657	1.0000	0.3163	0.5028	−0.3541	0.6329
FDI	0.2079	0.3163	1.0000	0.0291	−0.0384	0.4674
LF	−0.4588	0.5028	0.0291	1.0000	−0.3284	−0.0211
IN	0.1485	−0.3541	−0.0384	−0.3284	1.0000	−0.1661
MS	0.1953	0.6329	0.4674	−0.0211	−0.1661	1.0000

Table 3: ADF unit root summary

Variable	Countries	Stationary at level	Stationary after 1st Diff
REI	10	1	8
FD	10	4	6
FDI	10	2	5
LF	10	4	4
IN	10	3	1
MS	10	5	6

Table 4: Panel DOLS long-run results

Variable	Coefficient	Std. error	t-statistic	Prob.
FD	−0.0410	0.0199	−2.056	0.0398
FDI	−0.8767	0.2883	−3.041	0.0024
LF	0.1637	0.1997	0.820	0.4125
IN	−0.1125	0.0786	−1.432	0.1520
MS	0.0910	0.0338	2.690	0.0072

Table 5: Dumitrescu–hurlin panel causality test (lag=1)

Null hypothesis	$\bar{W}$	$\bar{Z}$	Prob.	Conclusion
FD does not cause REI	2.0176	2.1586	0.0309	Reject H_0
REI does not cause FD	4.1573	6.6977	0.0000	Reject H_0

not being effectively channeled towards renewable energy projects but perhaps towards competing sectors.

FDI is also negative and significant (−0.8767, P = 0.0024), which could reflect the concentration of foreign investment in oil, gas, and other non-renewable sectors in the MENA region. Money supply (MS) has a positive and significant coefficient (0.0910, P = 0.0072), indicating that liquidity expansion supports renewable investment. LF and IN are not statistically significant.

4.6. Granger Causality Tests

The Dumitrescu–Hurlin panel causality results in Table 5 reveal bi-directional causality between FD and REI. Financial development Granger-causes renewable energy investment (P = 0.0309), while REI also Granger-causes financial development (P < 0.0001). This two-way relationship suggests a feedback loop in which finance facilitates renewable investment, which in turn stimulates further financial sector activity.

5. CONCLUSION AND RECOMMENDATIONS

This study investigated the long-run relationship and causal dynamics between financial development and renewable energy investment in selected MENA countries over the period 2000-2023, employing a Panel Dynamic Ordinary Least Squares (DOLS)-style estimator and Dumitrescu–Hurlin panel causality tests. The descriptive analysis revealed significant disparities across the region, where some economies have established deep credit markets and maintained substantial liquidity. At the same time, renewable energy investment remains uneven and largely concentrated in a limited number of frontrunner countries. This divergence highlights the complexity of the financial–energy nexus in the MENA region, where structural differences in market maturity and policy frameworks significantly influence investment outcomes.

The empirical findings highlighted three notable results. First, financial development exhibited a negative and statistically significant effect on renewable energy investment, suggesting that financial resources in the region are often directed toward traditional and fossil-fuel-based sectors instead of being allocated to renewable projects. Second, foreign direct investment also showed a negative and significant relationship with renewable energy, reflecting the persistent dominance of oil and gas projects in attracting foreign capital. Finally, money supply demonstrated a positive and significant effect, pointing to the importance of domestic liquidity expansion in facilitating renewable energy financing and reducing the reliance on external capital inflows. Together, these outcomes emphasize the dual challenge of reorienting financial flows and ensuring that financial deepening contributes to the energy transition.

The causality analysis further revealed a bidirectional relationship between financial development and renewable energy investment, implying a feedback mechanism through which financial market expansion supports renewable projects, which in turn stimulate growth within the financial sector by generating increased demand for investment instruments and project financing. This interdependence highlights both the opportunities and vulnerabilities inherent in the finance–energy nexus. While deeper financial markets have the potential to enhance renewable energy deployment, the absence of targeted mechanisms risks reinforcing the dominance of conventional energy sectors. Thus, the findings suggest that strategic financial reforms and policy alignment are necessary to maximize the developmental benefits of financial systems in supporting sustainable energy transitions.

From a policy perspective, the results carry several important implications. Aligning financial development with energy transition objectives requires interventions such as green credit guidelines, renewable energy lending quotas, and the implementation of sustainable finance frameworks to ensure that financial depth translates into tangible renewable energy investment. Likewise, the reorientation of foreign direct investment flows is essential, as incentives such as tax exemptions, risk guarantees, and streamlined permitting procedures could redirect foreign capital from fossil fuel projects toward renewable ventures. Expanding domestic liquidity through instruments such as green bonds, concessional lending, and the establishment of renewable energy investment funds can further strengthen financing capacity. At the same time, integrating renewable projects into mainstream financial markets through securitization and renewable energy-backed securities could reinforce the positive feedback loop between finance and energy. Future research should focus on sectoral disaggregation of financial flows, incorporation of governance and institutional quality indicators, and the exploration of structural shifts arising from global oil price volatility or major policy reforms, while also expanding datasets to project-level observations for greater precision and causal inference.

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