

The Role of Education in Shaping Sustainable Finance and Environment Relationships in MENA Countries

Anass Hamadelneel Adow ^{1*}, Haider Mahmood ², Muhammad Tanveer ³ and Maham Furqan ⁴

- ¹ Department of Accounting, College of Business Administration, Prince Sattam Bin Abdulaziz University, 173 Alkharj 11942, Saudi Arabia.
² Department of Finance, College of Business Administration, Prince Sattam Bin Abdulaziz University, 173 Alkharj 11942, Saudi Arabia.
³ Business Administration Department, College of Business, Imam Mohammad Ibn Saud Islamic University (IMSIU), Riyadh 11564, Saudi Arabia.
³ The World Bank 1818 H Street, NW Washington, DC 20433 USA.

* Corresponding author: a.adow@psau.edu.sa

ABSTRACT: Education can play a vital role in moderating the Financial Development (FD), Energy Consumption (EC), and the environment nexus as per the Sustainable Development Goals 7 and 13. Thus, the aim of this research is to explore such linkages in the framework of the Environmental Kuznets Curve (EKC) in 15 MENA economies for the period 1999-2022. For this purpose, Cross-Sectional Dependence (CD) econometric techniques are applied. The CD is validated in the individual series and in the hypothesized models as well. The cointegration is also validated in the models. Moreover, the EKC is supported in the MENA region in the regression results. In the long and short run, FD and education reduce carbon emissions, and EC raises them. Moreover, education moderates the connection between FD and emissions. Thus, education helps to enhance the environmental benefits of FD. However, education could not moderate the impact of EC on emissions. These results suggest enhancing financial and environmental literacy to support a sustainable environment in the MENA region.

Keywords: sustainable development goals (SDGs), education, financial development, carbon emissions, energy consumption.

I. INTRODUCTION

Financial Development (FD) is growing in the MENA countries as per their national goals of diversification from natural resource sectors. However, the growing FD may have environmental consequences for these economies due to excessive dependence on the resource and industrial sectors. For instance, greater access to finance can increase emissions by fueling investment in energy-intensive industries like oil, gas, cement, and heavy manufacturing in the MENA economies [1], which can significantly contribute to emissions. In the oil-exporting MENA countries, the financial sector tends to prioritize fossil fuel-related projects due to their quick returns. Thus, FD may provide easier access to loans for petrochemical and construction ventures in MENA economies. Moreover, FD may also raise consumer credits, which can boost consumer spending on energy-intensive goods like cars and air conditioners in the hot-climate MENA region. On the other hand, in the positive aspects of FD, the financial sector may finance clean energy projects and green innovation [2], which can help reduce environmental problems. For instance, some MENA countries have focused on issuing green bonds to support solar energy and clean transportation

initiatives. Moreover, FD may promote Small and Medium Enterprises (SMEs) to adopt green technologies and energy sources [3].

In another important dimension, Energy Consumption (EC) can be massively responsible for carbon emissions, as most MENA economies are still mainly relying on fossil fuels for their energy needs. For instance, fossil fuels are major energy sources for electricity generation, heating, cooling, transportation, and industrial activities in most MENA economies [4]. Particularly, EC can be responsible for environmental degradation in those oil-rich MENA countries, which are consuming energy without a shift toward renewable energy sources. However, some MENA countries are transforming their EC toward renewable sources [5]. For instance, some MENA economies are following the Sustainable Development Goals (SDGs) and expanding solar power capacity and nuclear energy for electricity generation, which can reduce emissions. In addition, the adoption of electric vehicles and smart grid technologies can further support a cleaner environment by improving energy efficiency and reducing emissions per unit of EC. In this case, the effect of EC on the environment can be neutral or even pleasant in the MENA region.

Education would play a moderating role in shaping the environmental impacts of FD and EC. For instance, education can provide awareness to individuals and businesses about the long-term environmental risks connected with fossil fuel consumption [6], which can increase demand for renewable energy and energy-efficient technologies for both production and consumption. Moreover, education can motivate the financial sector to fund clean energy and green infrastructure, and to avoid funding for fossil fuel projects [7]. Similarly, education can motivate investors for green projects and consumers to buy energy-saving products. Education can develop human capital to start low-carbon businesses, to develop clean technologies, and to design sustainable finance systems [8], which can redirect investments from polluting sectors to environmentally friendly projects. Lastly, education can help to develop professionals in government and regulatory agencies, which can improve institutional quality to enforce environmental risk assessments and implement green finance regulations to align the FD with environmental objectives.

Considering the importance of FD in determining the environment, the MENA has explored the nexus between FD, EC, and emissions. However, the MENA literature is indecisive on the nexus between FD and the environment. For example, Omri et al. [9] could not validate the causal relationship between FD and emissions. On the other hand, Ekwueme and Zoaka [10] and Zhou et al. [11] reported the negative influence of FD on emissions, and Awan et al. [12] found a positive effect of FD on emissions. However, no study could explore the expected moderating role of education in the association between EC, FD, and emissions. This study contributes to the MENA literature by integrating education as a moderating factor in the nexus of FD, EC, and carbon emissions to add novelty to this relationship. For this purpose, a sample of 15 MENA economies is utilized from 1999-2022. Moreover, Cross-Sectional Dependence (CD) techniques are applied due to the economic, environmental, and geographical interdependence of MENA economies. Thus, the estimated results would have great educational policy implications to understand how enhancing educational outcomes can strengthen the positive environmental role of FD and EC in the MENA region.

II. LITERATURE REVIEW

The literature is divided into 4 parts to understand the environmental effects of FD, EC, and education in the global, regional, country-specific, and MENA studies.

1. THE ENVIRONMENTAL EFFECTS OF FD

The recent literature realizes the importance of FD in mitigating climate change. For instance, Bilgili et al. [13] utilized the quarterly data from 1990-2022 in the US by applying wavelet analysis and found that financial instruments like debt securities, loans, and liabilities were effective in lowering emissions at medium-term frequency bands. Thus, FD moved the financing toward green projects and sustainable business models to support environmental sustainability. However, Salam et al. [14] scrutinized BRI countries and reported that FD increased CO₂ emissions. Moreover, BRI's trade flows to China show mixed results. Imports from China reduced emissions, and exports increased them. Similarly, Khalid et al. [15]

investigated Egypt and found that FD, EC, and economic growth reduced environmental quality. Moreover, feedback was reported between EC and growth.

In a nonlinear analysis, Annor et al. [16] examined Sub-Saharan Africa (SSA) from 1989-2018 with different levels of Human Development Index (HDI) and found the EKC between FD and ecological footprint in the high HDI sample. However, FD had a U-shaped impact in the high HDI sample, an inverted U-shaped impact in the low HDI sample, and a negative impact in the middle HDI sample on CO₂ emissions. Cheng et al. [17] analyzed 82 countries from 1990-2019 and conducted the disaggregated FD analysis. The results showed that financial market access reduced emissions. Moreover, financial institutional access and efficiency reduced emissions. In addition, the environmental effect of FD was found to be more effective in developed countries. Sikhawal [18] examined 125 countries from 1991-2015 and found that FD increased emissions, and the magnitude of effect was found to be more significant in countries with lower initial emissions. Thus, less industrialized nations were found to be more vulnerable to environmental deterioration with FD.

Ye et al. [19] explored 209 economies from 2000-21 and substantiated the N-shaped relationship between digitalization and carbon emissions. Moreover, FD played a moderating role, which improved the influence of digitalization to promote green finance. Elatroush [20] explored 60 emerging countries from 1980-2021 and found both positive and negative environmental impacts of FD, which depended on country clusters based on variations in development patterns, technology levels, and socioeconomic conditions. Kharb et al. [21] investigated the role of FD in determining CO₂ emissions through Foreign Direct Investment (FDI) and technological innovation in emerging economies. The findings suggested that FD supported green technological advancement, which reduced emissions. However, FD also attracted FDI in the pollution-intensive sector and corroborated the Pollution Haven Hypothesis.

Alnsour et al. [22] studied the environmental effects of FDI and FD in Jordan from 1990-2022 and reported that both drivers positively contributed to emissions. Moreover, feedback effects were also found between FD, FDI, and trade openness. Jalil and Rauf [23] investigated 100 countries from 1980-2020 and stated that FD significantly reduced CO₂ emissions by supporting cleaner energy. Moreover, the Environmental Kuznets Curve (EKC) was substantiated in most countries. However, fossil fuel dependence reduced the positive environmental effects of FD. Wei and Nie [24] analyzed Indonesia from 1980-2021 and found that FD could not significantly affect CO₂ emissions. Moreover, EC and growth raised emissions, and natural resources mitigated emissions. Wang et al. [25] analyzed Africa and found that technological innovation improved environmental outcomes. However, the FD, agriculture, and manufacturing sectors raised environmental problems. Thus, FD supported pollution-intensive activities in Africa due to an underdeveloped green financial market.

Larick and Donou-Adonsou [26] investigated and confirmed the EKC between digitalization and emissions. Moreover, FD reduced emissions in less digitally advanced countries. However, this effect diminished with the increasing level of digitalization. Saadaoui et al. [27] assessed Turkey and found that FD increased CO₂ emissions. However, hydroelectric power, FDI, and geopolitical risk reduced them. Moreover, a bidirectional causality between FD and emissions was also found. Rahman et al. [28] examined Pakistan and substantiated the EKC in the industry and agricultural sectors. However, FD positively contributed to carbon emissions. Keho [29] investigated West Africa from 1990-2018 and found that FD and globalization raised the ecological footprint. Yu et al. [30] analyzed 57 mixed developing stage countries from 2000-17 and stated that financial depth mitigated carbon intensity. However, financial access and depth increased carbon intensity. Moreover, clean FDI and carbon pricing also moderated these effects.

The relationship between FD and pollution is context-dependent and diverse across countries and regions. Thus, recent literature finds both evidence of environmental improvements and degradation. FD helped reduce emissions in some developed financial systems by promoting green projects, supporting green innovations, and attracting clean FDI. However, FD usually contributes to environmental problems in developing economies with limited green financial infrastructure and dependence on pollution-intensive sectors. In addition, the effect of FD is also found to be nonlinear in some cases, which suggests the environmental effects of FD depend on a country's development and HDI.

2. EC AND THE ENVIRONMENT NEXUS

Yasin et al. [31] investigated the BRICS from 1995-2017 and stated that agricultural production, Renewable Energy Consumption (REC), and FD mitigated emissions. However, non-REC, forest rents, income, and domestic investment increased CO₂ emissions and ecological footprint. Similarly, Chen and Zhang [32] substantiated that income and EC increased CO₂ emissions. Adow et al. [33] scrutinized the GCC panel from 1990-2022 and stated that FD mitigated CO₂ emissions and substantiated the EKC. Moreover, urbanization and EC increased emissions. Manisha et al. [34] investigated the EKC in India from 2010-21 and validated the EKC between tourism and emissions. Moreover, feedback effects between tourism, EC, and emissions were also corroborated. Thus, the increasing carbon emissions would also threaten the sustainability of the tourism sector.

Gillani and Abbas [35] analyzed 41 Asian countries from 1996-2020 and found that FDI, EC, Gross Domestic Product (GDP), and government expenditure increased emissions. However, a combination of energy efficiency and trade mitigated them. Chen et al. [36] scrutinized 6 transition economies from 1970-2021, and found that EC increased GDP and CO₂ emissions. In turn, GDP also contributed to emissions, which validated the EKC. Triantafyllidou and Polychronidou [37] examined EU countries and found that fossil fuels contributed to CO₂ emissions. However, REC was reducing emissions. Ozparlak and Wang [38] analyzed the G-20 and found that EC positively raised GDP growth and carbon emissions. Somoye and Akinwande [39] investigated Nigeria and found that female participation, education expenditure, and REC reduced CO₂ emissions. Thus, REC reduced the negative environmental effects of EC.

By using daily global data, Ersin and Bildirici [40] used a period from 2012-22 and found that financial technology and EC caused CO₂ emissions with feedback effects. Pradhan et al. [41] assessed South Asia and the G-7 from 1996-2021 and found that the rising GDP increased both EC and CO₂ emissions. Moreover, EC and CO₂ emissions are also causing GDP growth. Furthermore, FD and population growth further intensified EC in South Asia, and REC reduced CO₂ emissions in the G-7 countries. Xie and Bui [42] studied China and stated that trade and FDI caused REC and non-REC. Consequently, REC helped reduce CO₂ emissions. However, the non-REC raised CO₂ emissions. Rahman [43] explored Lithuania and found that the EC significantly contributed to CO₂ emissions. However, financial globalization worsened emissions, and trade could not affect emissions. The literature shows that EC generally increases emissions due to non-REC dependence. However, increasing REC and energy efficiency helps to generate pleasant environmental effects of EC.

3. ENVIRONMENTAL EFFECT OF EDUCATION

The studies also investigated the influence of education on the EC and emissions nexus. Zafar et al. [44] analyzed Asia from 1990-2018 and stated that education improved environmental quality. However, GDP and EC significantly worsened it. Moreover, education and urbanization caused GDP and emissions. Maranzano et al. [45] examined 17 European OECD countries and tested and validated the Educational EKC hypothesis. Thus, higher levels of schooling mitigated the pollution and income relationship in countries with high income inequality. However, Zhang et al. [46] reported the inverse findings. Education and FD increased CO₂ emissions. However, ICT positively contributed to environmental quality. Osuntuyi and Lean [47] examined the global data and found that education raised environmental degradation universally in a direct effect. However, education moderated and reduced the role of EC in pollution in wealthier nations. However, education intensified this relationship in the case of poor countries. Thus, the role of education depended on the level of development. Moreover, EC increased environmental problems in all countries' groups.

Osuntuyi and Lean [48] examined 23 African countries to capture direct and indirect environmental effects of education and found that education aggravated environmental degradation directly and also indirectly through raising EC. Thus, education without environmental awareness accelerated the environmental problems in Africa. Qamruzzaman [49] examined eight resource-rich countries and found that income from natural resources raised CO₂ emissions. However, education and green technology helped reduce carbon emissions and ecological footprints. Moreover, financial inclusion raised environmental degradation. Qi [50] assessed rural China and found that education significantly improved the

environmental profile of rural China. Garg et al. [51] emphasized the roles of education and governance in ASEAN economies and found that good governance, coupled with education, mitigated the adverse effects of natural resource depletion.

Bâra et al. [52] investigated European sub-regions and found that education, urbanization, and REC showed heterogeneous effects on CO₂ emissions in Nordic, Baltic, and South-Eastern European countries, which reflected diverse policy efficacy and governance capacities in these regions. Cheng et al. [53] investigated the gender dimension in education and found that reducing educational gender inequality reduced carbon emissions in developing nations. Li [54] examined China and found that population, GDP, and industrial activity increased emissions. However, advancements in higher education and technological innovation significantly reduced them. Xing and Imran [55] analyzed BRICS and revealed that REC and education contributed to lowering CO₂ emissions. Moreover, the interconnected roles of communication technology and financial efficiency also helped to achieve sustainable growth.

Sart et al. [56] analyzed the EU from 2000-21 to investigate the importance of education in accelerating Renewable Energy Transitions (RET) and found feedback between REC, economic freedom, FD, and GDP. However, unidirectional causality was found from education to REC. Moreover, economic freedom, GDP, and education raised REC. Thus, education in the EU was a significant tool in raising REC. However, FD reduced REC. Lee et al. [57] explored 151 countries and stated that tertiary education played a pivotal role in combating CO₂ emissions in wealthier nations. Thus, education helped in tracing the EKC turning point. He et al. [58] analyzed China's carbon neutrality goals and found that education and technological innovation reduced emissions, which promoted green growth. Sahu et al. [59] investigated 31 OECD countries from 1998-2020 and found that industrialization and urbanization raised CO₂ emissions. However, education moderated these effects.

The literature corroborates that education mostly improves environmental outcomes by reducing EC, encouraging REC, and promoting green technologies in high-income and developed countries. However, education has mostly a direct adverse effect on the environment in low-income economies due to raising fossil fuel consumption in the presence of low-quality governance and limited access to green technologies. In addition, education moderated the adverse environmental effects of many pollution drivers.

4. THE MENA AND THE LITERATURE GAP

Omri et al. [9] confirmed the EKC in 12 MENA economies from 1990-2011. Furthermore, the feedback effects were reported between emissions and trade, and GDP. However, FD could not affect CO₂ emissions. Ekwueme and Zoaka [10] explored 10 MENA economies from 1970-2017, and FD reduced CO₂ emissions. However, trade openness and EC significantly contributed to higher emissions. Furthermore, the EKC was also corroborated. Zhou et al. [11] investigated the moderating effect of regulations and stated that FD in banking, financial, and private sectors reduced ecological footprint in the MENA region. Moreover, environmental regulations positively moderated this relationship. Charfeddine and Kahia [60] substantiated that REC and FD had minute effects on emissions. Awan et al. [12] scrutinized the impact of FD on environmental degradation in the MENA and found that globalization and FD reduced environmental quality. However, the EKC was substantiated.

The MENA literature consistently validates the EKC. Moreover, EC increases emissions, but REC has a minute effect on emissions due to the heavy dependence of MENA economies on fossil fuels. The effect of FD on emissions is not uniform. For instance, FD showed a neutral effect on the environment [9], a pleasant effect [10, 11], and an adverse effect [12]. Thus, this relationship needs more investigation, and the present research explores this relationship by assuming the moderating role of education in the connection among EC, FD, and carbon emissions.

III. METHODOLOGY

The methodology section is divided into three subsections.

1. MODEL AND ITS THEORETICAL JUSTIFICATION

The basic determinant of emission is economic growth in the EKC theory, which explains a nonlinear effect [61]. In the EKC, the scale effect increases EC in the first phase of development. However, after reaching a certain development level, countries may understand the significance of a cleaner environment and invest in clean technologies and sectors, which may achieve the technical and composition effects. FD may play an active role in achieving scale, technique, and composition effects. For instance, FD may have scale effects due to financing the pollution-oriented sectors in the MENA region, due to the overdependence of this region on resource and industrial sectors like oil, gas, cement, construction, and heavy manufacturing [1]. Moreover, FD can provide consumer loans, which may be directed toward energy-intensive household machinery and transport. Nevertheless, MENA economies are targeting RET [5], and FD may support this RET. For instance, FD may provide finance to clean energy projects, green innovation, and cleaner sectors [2]. In addition, education would play a moderating role in defining the environmental effects of EC and FD. For instance, education can spread awareness among households and business sectors to adopt clean energy in their production and consumption [6]. Thus, environmental awareness with education may promote the adoption of energy-efficient technologies. Moreover, education can also spread awareness of doing environmentally friendly projects and business activities [8]. Education is also a source of digital transformation in an economy, which can enhance productivity and reduce emissions from economic activities [62, 63]. Moreover, education can be integrated with ethical, cultural, and legal dimensions [64], which can encourage society to remain environmentally friendly. Thus, education can help in tracing the second stage of the EKC. Keeping in mind these theoretical arguments, Equation 1 is hypothesized to examine the impact of EC and FD on emissions without testing the moderating effect of education. Equation 2 hypothesizes the role of education as a moderator.

$$CEit = f(Yit, Yit2, FDi, ECit) \quad (1)$$

$$CEit = f(Yit, Yit2, FDi, ECit, EDUit, FDi * EDUit, ECit * EDUit) \quad (2)$$

2. DATA COLLECTION

The sample of the study includes the dependent variable (carbon emissions) and independent variables (GDP per capita, financial development, energy consumption, and education). In equations 1 & 2, CEit is the natural log of CO₂ emissions in tons per capita, which is a dependent variable. In the independent variables, Yit is the natural log of per capita GDP in constant US dollars, and Yit2 is a square term of Yit. FDi is the natural log of the percentage of domestic credit to the private sector of GDP, which is a proxy of financial development. ECit is the natural log of per capita energy use, kg of oil equivalent. EDUit is the natural log of the total pupils of primary and secondary education percentage of the total population. FDi*EDUit and ECit*EDUit are interactions of education with FD and EC, respectively, to test the moderating role of education. All data is obtained from the World Bank [65] for the period 1999-2022 for 15 MENA economies. Some series are interpolated and extrapolated to fill the missing observations.

3. RESEARCH DESIGN AND ECONOMETRIC STRATEGY

Research design includes Cross-sectional Dependence (CD) econometric techniques as the series of MENA economies would have Cross-sectional Dependence (CD) due to geographical locations, common climate, and economic policies. Thus, CD tests are performed on individual series and the sets of relationships to test the CD in the series and their hypothesized relationships. For this purpose, Pesaran's [66] CD test is applied in the following way:

$$CD_{adj} = \left[\sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^N p_{ij} - \mu \right] / \sigma \quad (3)$$

In equation 3, p_{ij} shows the covariance between the time series of all MENA economies to test the expected CD. μ and σ are means and standard deviations. Slope Heterogeneity (SH) is a common problem in the panel models and is tested by applying Pesaran and Yamagata's [67] test in the following way:

$$\Delta = \sqrt{N} \left(\frac{S_N - k}{\sqrt{2k}} \right) \quad (4)$$

$$\Delta_{adj} = \sqrt{N} \left(\frac{S_N - E(S_N)}{\sqrt{\text{Var}(S_N)}} \right) \quad (5)$$

k shows the number of parameters, and S_N is the average of individual heterogeneous slopes (S_i). Variances capture the expected variation in the slopes. With CD, the ordinary unit root tests could not perform well to conclude the right stationary decision. Thus, Pasaran's [68] CADF test is applied in the following way:

$$\Delta w_{it} = b_0 + b_{1i}w_{it-1} + b_{2i}\overline{w_{t-1}} + b_{3i}\overline{\Delta w_t} + \sum_{j=1}^k b_{4ij}\Delta w_{it-j} + u_{it} \quad (6)$$

Equation 6 will be tested with a null hypothesis of a unit root, and the conclusions will be rechecked by applying the following statistic:

$$CIPS = \frac{1}{N} \sum_{i=1}^N CADF_i \quad (7)$$

Equation 7 captures the average of CADF results and provides a consistent result to conclude about the stationarity. After testing the CD and unit root in the series, we may proceed to cointegration analysis. We use the following statistics of Westerlund [69] for this purpose:

$$G_t = N^{-1} \sum_{i=1}^N \frac{\hat{\Omega}_i}{\hat{\sigma}_i} \quad (8)$$

$$G_a = N^{-1} \sum_{i=1}^N T \widehat{\Omega}_i \quad (9)$$

$$P_t = \frac{\sum_{i=1}^N \hat{\Omega}_i}{\sqrt{\sum_{i=1}^N \hat{\sigma}_i^2}} \quad (10)$$

$$P_a = \sum_{i=1}^N T \widehat{\Omega}_i \quad (11)$$

Equations 8-11 are utilized to test the cointegration in the hypothesized models of the present study. After applying cointegration, long and short run effects will be estimated by utilizing the CD-ARDL of Chudik et al. [70]:

$$\Delta CE_{it} = g_{1i}CE_{it-1} + g'_{2i}x_{it-1} + c_1\overline{CE_{t-1}} + c_2\overline{x_{t-1}} + \sum_{j=1}^k g_{3ij}\Delta CE_{it-j} + \sum_{j=0}^k g'_{4ij}\Delta x_{it-j} + v_{it} \quad (12)$$

In Equation 12, x is a vector of explanatory variables. $\overline{CE_t}$ and $\overline{x}$ are cross-country averages of lagged variables.

IV. DATA ANALYSIS

All variables and their interaction terms in Table 1 exhibit significant CD with p-values below 0.01. Thus, CD exists in all variables across the MENA countries. Moreover, CD is also corroborated in the models of carbon emissions, which suggests applying CD econometrics. Thus, all countries in the panel are interconnected due to geographical location, common policies, fossil fuel dependence, and common

industrial structures. In addition, SH is also corroborated in the models with significant Δ and Δ_{adj} statistics. It implies that the association between the variables and emissions differs significantly across nations.

Table 1. CD and SH tests.

Variables	CD test	SH	
	CD _{adj}	Δ	Δ_{adj}
CE _{it}	5.271 (0.000)		
Y _{it}	1.964 (0.064)		
Y _{it} ²	1.712 (0.087)		
FD _{it}	6.754 (0.000)		
EC _{it}	5.624 (0.000)		
EDU _{it}	7.549 (0.000)		
FD _{it} *EDU _{it}	3.527 (0.000)		
EC _{it} *EDU _{it}	2.333 (0.021)		
Residual from Equation 1	6.432 (0.000)	28.712 (0.000)	30.193 (0.000)
Residual from Equation 2	6.081 (0.000)	27.836 (0.000)	28.849 (0.000)

In Table 2, CIPS and CADF tests indicate the non-stationarity of all variables on their levels, as the estimated test statistics could not exceed the critical values. However, the first-differenced variables are stationary.

Table 2. Stationarity tests.

Variables	Level		Δ	
	Intercept	Intercept and trend	Intercept	Intercept and trend
CIPS test				
CE _{it}	-2.071	-2.131	-3.099***	-3.247***
Y _{it}	-0.597	-0.688	-2.913***	-3.095***
Y _{it} ²	-0.470	-0.613	-3.108***	-3.141***
FD _{it}	-1.200	-1.289	-3.390***	-3.467***
EC _{it}	-2.755	-2.156	-4.384***	-4.869***
EDU _{it}	-0.965	-1.524	-5.024***	-5.463***
FD _{it} *EDU _{it}	-1.155	-0.989	-3.376***	-3.454***
EC _{it} *EDU _{it}	-1.703	-1.296	-4.279***	-4.162***
CADF Test				
CE _{it}	-2.325	-2.280	-5.858***	-6.317***
Y _{it}	-0.828	-0.926	-4.840***	-5.120***
Y _{it} ²	-0.669	-0.846	-5.255***	-5.088***
FD _{it}	-1.714	-1.856	-7.908***	-7.297***
EC _{it}	-2.062	-2.438	-7.089***	-6.536***
EDU _{it}	-1.678	-1.974	-6.854***	-7.021***
FD _{it} *EDU _{it}	-0.794	-0.585	-5.186***	-5.518***
EC _{it} *EDU _{it}	-2.094	-2.015	-6.453***	-6.074***

Note: *** represents stationarity at 1%.

Table 3 reports the results of four statistics of the Westerlund [66] caring for both CD and SH issues in the estimations. In the model of equation 1, *Gt*, *Pt*, and *Pa* statistics are significant, which validates cointegration

in this model. In the model of equation 2, Pt and Pa statistics are significant and corroborate cointegration in this model.

Table 3. Cointegration analysis.

Statistics	Model of Equation 1	Model of Equation 2
Gt	-6.910 (0.114)	-6.220 (0.171)
Ga	-2.031 (0.085)	-2.373 (0.113)
Pt	-6.782 (0.055)	-10.017 (0.000)
Pa	-5.163 (0.037)	-7.331 (0.000)

In Table 4, the estimates based on CD-ARDL are presented. In the long run, both models of equations 1 and 2 validate the EKC hypothesis with positive and negative parameters of Y_{it} and Y_{it}^2 , respectively. The turning points are estimated at 25,135 and 23,300 constant US dollars in Models 1 and 2, respectively. Moreover, the coefficients of FD are negative in both models. Thus, FD helps reduce carbon emissions in the MENA region. A 1% increase in FD would reduce carbon emissions by 0.568% and 0.465% in models 1 and 2, respectively. However, the coefficients of EC are positive in both models, and EC is contributing to carbon emissions in the MENA region. A 1% increase in EC can increase carbon emissions by 0.796% and 0.865% in Models 1 and 2, respectively. In Model 2, we hypothesize the moderating effects of education. A 1% increase in education may reduce carbon emissions by 0.163 % in Model 2. Moreover, the coefficient of $FD_{it} * EDU_{it}$ is also negative. Thus, education significantly moderates this relationship, and a 1% increase in education may increase the environmental benefits of FD by 0.116%. However, education could not moderate the association between EC and emissions. Thus, education could not affect the EC-emissions relationship.

Table 4. Long and short run estimates.

Regressors	CS-ARDL of Equation 1	CS-ARDL of Equation 2
Long run		
Y_{it}	9.362 (0.027)	11.625 (0.071)
Y_{it}^2	-0.462 (0.065)	-0.578 (0.042)
FD_{it}	-0.568 (0.033)	-0.465 (0.011)
EC_{it}	0.796 (0.076)	0.863 (0.045)
EDU_{it}		-0.163 (0.000)
$FD_{it} * EDU_{it}$		-0.116 (0.000)
$EC_{it} * EDU_{it}$		0.265 (0.265)
Short run		
Y_{it}	14.221 (0.022)	14.523 (0.020)
Y_{it}^2	-0.698 (0.060)	-0.721 (0.015)
FD_{it}	-0.620 (0.028)	-0.654 (0.056)
EC_{it}	1.051 (0.070)	1.111 (0.049)
EDU_{it}		-0.209 (0.002)
$FD_{it} * EDU_{it}$		-0.185 (0.001)
$EC_{it} * EDU_{it}$		0.281 (0.270)
ECT_{t-1}	-0.717 (0.000)	-0.629 (0.000)

In the short run, the EKC is substantiated in both models, with estimated turning at 26,554 and 23,657 constant US dollars in Models 1 and 2, respectively. A 1% increase in FD could reduce 0.620% and 0.654% of emissions in Models 1 and 2, respectively. However, a 1% increase in EC can increase emissions by 1.051% and 1.111% in Models 1 and 2, respectively. In Model 2, 1% increase in education may reduce carbon emissions by 0.209%. Moreover, education moderates the association between FD and emissions, and 1%

increase in education can increase the environmental benefits of FD by 0.185%. However, education could not moderate the EC-emissions nexus. The coefficients of ECTt-1 show that any short-run disequilibrium can converge to the long-run path with a speed of 0.717% and 0.629% per year in Models 1 and 2, respectively.

V. DISCUSSIONS

As per the results, the EKC hypothesis is validated as suggested by the theoretical arguments of Grossman & Krueger [61]. Thus, increasing GDP raises emissions at first and reduces them after a later stage of the EKC, which may be due to a shift toward cleaner technologies and more sustainable development pathways. However, 8 out of 15 investigated countries' GDP per capita is less than the turning points. Thus, most MENA countries are still facing the environmental consequences of economic growth. In the empirical analysis, Adow et al. [33] validated the EKC hypothesis [33]. However, the literature has also reported the monotonic positive effect of economic growth on emissions [32, 35].

FD reduces carbon emissions. Thus, FD in the MENA region is supporting environmentally friendly investments, green financing, and efficient resource allocation. Thus, the FD in the MENA region is mature enough to achieve the net technique and composition effects of financial markets. In the same way, many empirical studies validated the negative effect of FD on emissions [13, 17, 21, 33]. On the other hand, the literature has also reported the positive effect of FD on emissions [14, 15, 18, 22, 25, 27-29] and the insignificant effect of FD on emissions [24]. Another dimension of literature has reported the nonlinear effect of FD on emissions [16, 20, 26, 30], which validated that FD could have a different effect on the environment with different levels of financial development. Moreover, the findings show that education significantly moderates the positive environmental impact of FD. Thus, educated populations help the MENA region to show environmentally responsible behavior, demand greener investments, and support environmentally friendly financial policies. In addition, education can develop human capital to develop mechanisms in financial markets to perform in an environmentally friendly manner. Similarly, Sahu et al. [59] also corroborated that education positively moderated the environmental effects.

The results also confirm that EC raises emissions. This result corroborates the region's dependence on fossil fuels for domestic energy needs, government revenues, and export revenues. Recently, many economies have transformed some EC to renewable sources. However, the results confirm that fossil fuels are dominant in the energy sector, which is responsible for consistently increasing carbon emissions. Moreover, the high EC elasticity of emissions suggests that the energy structure remains carbon-intensive and the transition to cleaner energy sources is still minute, which could not support a clean environment at large. Moreover, education could not significantly moderate the EC-emissions nexus. This indicates that the MENA region's EC is still environmentally harmful, even with educated societies. This result matches the fact that some MENA economies provide energy price subsidies, which reduce the incentives for REC, and are responsible for energy inefficiency in the production and consumption activities. The direct effect of education is found to be negative. Thus, education increases the awareness of the population to stay environmentally friendly. However, its effectiveness in other sectors is context-dependent. For instance, it helps reduce emissions from financial activities, but it still cannot achieve a significant reform in the energy sector. Similar to our findings, a lot of studies corroborated the positive effect of EC on emissions [24, 31-33, 35-38, 43]. However, REC helped reduce emissions [31, 39, 42].

VI. CONCLUSION

FD and EC are major drivers of carbon emissions in any economy, and education can moderate the association between FD, EC, and emissions. Thus, this study investigates the effects of FD and EC on carbon emissions in 15 MENA economies from 1999-2022 and also tests the moderating role of education in the EKC framework. Due to the superiority of Model 2 in carrying the moderating role of education, we conclude the study based on its results. The empirical results support the EKC hypothesis with turning points 23,300 and 23,657 in the long and short runs, respectively. 7 out of 15 investigated economies have achieved these turning points with their average GDP per capita during the sample period. However, 8 MENA economies are still facing the environmental problems of economic growth. FD mitigates emissions. In the direct effect,

education also helps reduce emissions in the long and short run. However, EC is raising emissions. Furthermore, education moderates the relationship between FD and emissions, but it cannot moderate the connection between EC and emissions. On the whole, education and FD achieve significant environmental benefits, which are aligned with national MENA policies and the SDGs of the United Nations. However, the energy sector is still carbon-intensive, and renewable energy transition efforts in the MENA region cannot help reduce environmental problems from the EC.

1. POLICY IMPLICATIONS

The results of the EKC hypothesis suggest that the economic growth of 8 MENA countries contributes to environmental degradation. Thus, these MENA countries should prioritize sustainable growth strategies by encouraging cleaner production technologies and low-carbon infrastructure. Moreover, income dependence on pollution-oriented sectors should be reduced, and the economies should transform toward cleaner sectors to achieve economic growth. EC also significantly contributes to carbon emissions. Thus, MENA governments should remove energy price subsidies on an urgent basis to reduce the environmental problems from the EC. Moreover, the fossil fuel-based energy-intensive production and consumption activities should be heavily taxed, and the generated revenue should be invested in renewable energy infrastructure development and to support the production and consumption activities utilizing renewable energy. FD helps reduce carbon emissions. The government should further support the financial sector to increase the positive environmental effects of FD. The education directly helps mitigate carbon emissions. So, the government should increase funding for educational attainment in the public sector and should also support the private educational institutions. Education also moderates the FD-emissions nexus. Thus, the government should further support the educational institutes, which include environmental and financial literacy in their curriculum.

2. LIMITATIONS

This study faces limitations in terms of data availability. Thus, the analysis is limited to 15 MENA economies. It reduces the generalizability of the findings to other regions with different socio-economic and institutional structures, and to compare the results among different regions. Moreover, the study utilizes aggregate data. It obscures within-country heterogeneity like regional disparities, sectoral energy intensity, and institutional capacity. Lastly, the moderating role of education is assessed through a single proxy of enrollment in primary and secondary education. Thus, it could not capture the multidimensional impact of education quality, skills, and awareness on environmental sustainability.

3. FUTURE RESEARCH DIRECTIONS

Future research can expand the sample of the study to include cross-regional comparisons with the MENA region, which would provide broader insights into the nexus between FD, EC, education, and emissions. Moreover, disaggregated datasets of sector-specific energy use, renewable energy shares, and education quality indicators would enhance the depth of analysis to inform sector-specific policies. In addition, advanced econometric techniques of dynamic spatial models, machine learning-based inference, and panel quantile regressions could be employed to test the robustness of findings from conventional econometric techniques.

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Authors Contribution

All authors made an equal contribution to the development and planning of the study.

Conflict of Interest

The authors have no potential conflicts of interest or such divergences linked to this research study.

Data Availability Statement

Data are available from the corresponding author upon request.

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