

Renewable energy transition and climate change mitigation in MENA countries: do the digital transition matter

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Abstract :

The objective of this paper is to study, for the MENA region, the relationship between renewable energy adoption and climate change by incorporating digital transformation as a moderating element between 1990 and 2021. We utilize panel cointegration methods to explicitly account for the possible issue of cross-sectional dependency.

The EKC hypothesis is rejected since these countries have not yet met the GDP threshold. Moreover, Data shows that renewable energy sources do not have a direct impact on CO2 emissions. However, trade, information and communications technology, and foreign direct investment have a negative impact on the environment. However, the combination of renewable energy and the digital shift can reduce CO2 emissions. Therefore, to reduce the effects of climate change, policy makers should jointly implement both energy and digital transitions.

Keywords : renewable energy, ICT, CO₂ emissions

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1. Introduction

Climate change has become more pronounced and noticeable over the past few decades. Both human life and the environment's quality are impacted by these changes (Charfeddine and Kahia, 2019). Reduced rainfall, rising temperatures, rising sea levels, floods, droughts, and an increased chance of fertile places becoming deserts have all been impacted by these changes. Numerous studies demonstrate that these climate changes have negative effects on future well-being (Brown et al., 2017). Furthermore, they exacerbate the consequences of urbanization, population and heightened economic activity on the availability of resources like energy, land, and water. According to a substantial body of research, the 20th century's economic boom and rising fossil fuel consumption are to blame for the historically high levels of greenhouse gas emissions that are causing these climate changes (Chen et al., 2022). As a result, to promote an ecologically friendly sector and lower emissions, climate change fighting policies aim to preserve energy and reduce emissions (Ben Youssef et al., 2018). According to the most recent research, energy transition and digital transition policies are seen as the primary means of preventing and coping with climate change (Charfeddine and Kahia, 2019).

Therefore, a first category of empirical studies has examined the effect of renewable energy on carbon dioxide emissions (Zoundi, 2017; Yao et al., 2019; Yang et al., 2021; Qi et al., 2014; Amri, 2017; Charfeddine and Kahia, 2021; Adams and Nsiah, 2019). However, a second category of studies has highlighted the relationship between ICT use and carbon dioxide emissions (Amri, 2018; Amri et al., 2019; Shah et al., 2022). Still, relatively few researches has examined the joint benefits of energy and digital transformations (Charfeddine and Kahia, 2019). For example, Shah et al. (2022) examined the effects of renewable energy and information and communication technology (ICT) on environmental quality with considering some control variables. They specifically looked at the BRICS countries' situation between 1990 and 2019. Their empirical

results show that the two mentioned factors contribute positively to the enhancement of the environment.

The aim of this work is to fill this gap in the literature .To do this, we look into how digital transformations and renewable energy might help mitigate climate change. More precisely, we look into how the relationship between renewable energy and CO2 emissions is tempered by the digital revolution. Unlike previous research, this work is the first to focus on how these factors interact to affect CO2 emissions. Furthermore, our work is the first to consider how the change to digitalization and the non-linear effects of renewable energy shift together. We also examine how certain transmission routes contribute to accelerating the digital and energy transitions required to tackle climate change.

The choice of MENA countries for the study is explained by several factors. First, this region is recording increasingly high levels of CO2 emissions per capita. Second, it is moving towards the energy and digital transition sectors (Ben Youssef et al., 2023). Finally, most countries in the MENA region have considerable potential for renewable energy production such as solar and wind energy, but they are also high-energy consumers. In the present study, we employ annual data covering the most recent accessible period of 1971-2019 in the case of MENA countries, using the panel cointegration approach to achieve our goals.

The rest of this paper is structured as follows: Section 2 presents the literature review; Section 3 describes the materials and methods; Section 4 presents the empirical findings; and section 5 summarizes the conclusion and policy implications.

2. Literature Review

A lot of studies have been done on how switching to renewable energy might help reduce climate change. There are two major categories into which this literature falls.

The first category concerns research that focuses on how the shift to renewable energy directly and linearly reduces climate change. Although academics, policy makers, and environmental scientists

recognize the potential climate-enhancing benefits of using renewable energy, the empirical results are contradictory. Zhang et al. (2023), for instance, looked at the impact of renewable energy sources on CO₂ emissions in the case of MENA countries between 1971 and 2015. Their empirical results show that the renewable energy boosts the quality of the environment.

In the same vein, Guo et al. (2023) examine how the use of renewable energy by the Jordanian economy between 1985 and 2019 improved its environmental sustainability. The results suggest that the use of renewable energy contributes positively to the achievement of environmental objectives. Moreover, Charfeddine and Kahia (2021) are curious about how information and communication technology variables, as well as the consumption of green energy category, boosts environmental improvement in the MENA context for 39 years. Their results support the idea that renewable energy has a beneficial influence whereas information and communication technology have a negative one. Contrary to the above-mentioned conclusions, the negative or negligible effects of green energy on gas emissions are proven in other studies. For instance, Adams and Nsiah (2019) looked at 28 Sub-Saharan African nations from 1980 to 2014. Their empirical research indicates that the advancement of the environment is negatively related to renewable energy using. Amri (2017) also concentrated on a few factors that affected Algeria's CO₂ emissions between 1980 and 2011. Because of its low participation in mix energy, the results of the ARDL with breakpoint approach demonstrate little effect of renewable energy determinants on CO₂ emissions.

These researches used linear models to investigate the relationship between the use of renewable energy and CO₂ emissions, yielding conflicting and contradictory results. More recent studies have demonstrated interest in the nonlinear relationship between renewable energy and environmental improvement, in contrast to earlier ones, in an attempt to explain these conflicting findings in the literature. For instance, Chen et al. (2022) examined the aforementioned association. The results demonstrate that using renewable energy has a positive effect on environmental quality after a certain threshold for consumption of renewable energy is met in the case of 97 countries between 1995 and

2015. In the present study, we use nonlinear models to explain these contradictory results in the literature.

The second category concerns research studies that focus on the channels through which the shift to renewable energy can slow global warming. Khezri et al (2022) examined the effects of renewable energy sources on environmental enhancement, taking into account economic complexity as a mitigating factor in determining the relationship between renewable energy and CO2 emissions in 29 Asia-Pacific countries from 2000 to 2018. They proved that, in nations with lesser levels of economic complexity, the renewable energy become benefit on environmental quality. Additionally, Kwakwa (2023) looked at the indirect benefits of renewable energy through institutional quality in the instance of various African countries between 2002 and 2021. The findings show that institutional quality in these nations can serve to attenuate the effect of renewable energies in lowering CO2 emissions. Additionally, Wang et al. (2022) paying particular attention to the moderating effect of financial growth in the context of 11 emerging nations between 1990 and 2015. The findings showed that one way to enhance the environment is through the interplay between renewable energy and financial development.

In light of the aforementioned, the majority of the literature focuses on the direct impact of energy transition on climate change mitigation. Although several recent studies have looked at the variables that influence this correlation, none have particularly looked at how information and communication technology condition the nature of this relationship.

For this, we formulate the following objective: demonstrate how information and communications technology can moderate the effects renewable energy transition on mitigating climate change.

3. Methodology and Analysis:

3.1 Data

We use a set of data from the World Bank Indicators (2022) that includes a few MENA countries and spans the years 1990–2021. Lebanon, Turkey, Tunisia, Saudi Arabia, Qatar, Oman, Morocco, Kuwait,

Jordan, Iran, Egypt, Bahrain, and Algeria are the nations included in this study. The choice of such a period is conditioned by the availability of data.

The variables taken into consideration in this study are CO2 emissions, the use of renewable energy, information and communication technologies, GDP, trade, financial development, and foreign direct investment. The measures and symbols for our variables are presented in Table 1.

Table 1: Variables presentation

Variable symbol	Variable	Variable measure
ICT	Information and communication technology	sum of mobile and fixed telephone subscription per 100 persons
GDP	Real GDP per capita	Gross domestic product in constant 2010 US\$
CO	CO ₂ emissions per capita	CO ₂ emissions in metric tons per capita
RW	Renewable Energy consumption	Share of Renewable energy consumption in percentage of total final energy consumption)
FID	Financial development	Domestic credit to private sector in percentage of gross domestic product
TO	Trade	sum of exports and imports in % of GDP
FDINV	Foreign direct investment	Foreign direct investment net inflows in % of GDP

3.2 Model

In this paper, to develop the model that examines the effect of renewable energy on CO2 emissions, we employ Dietz and Rosa's (1997) STIRPAT (Stochastic Impact by Regression on Population, Affluence and Technology model).

This latter model is inspired from Ehrlich and Holdren's (1971) IPAT (influence, population, affluence, and technology) mathematical identity where environmental impact (I) is the product of population (P) multiplied by affluence (A) multiplied by technology (T) as shown by this equation.

$$I = P * A * T \quad (1)$$

STIRPAT model differs from the IPAT one in that it includes a stochastic disturbance factor that enables the estimation and possible testing of hypotheses, in addition to assuming a more flexible relationship between the variables. The STIRPAT model is supplied by:

$$I_{it} = \alpha P_{it}^{\beta} A_{it}^{\gamma} T_{it}^{\delta} \varepsilon_{it} \quad (2)$$

In this specification, the subscript i denotes the countries, and the subscript t denotes the period. The terms α and ε_{it} represent the error disturbances and country-specific effects, respectively. After transforming the preceding equation logarithmically, we get a linear model as follows:

$$\ln I_{it} = \alpha + \beta \ln P_{it} + \gamma \ln A_{it} + \delta \ln T_{it} + \varepsilon_{it} \quad (3)$$

The country-specific coefficients in this model are indicated by α , whereas the coefficients to be estimated are β , γ , and δ . It is assumed that the new error term, ε_{it} , has an identical distribution and is independently distributed. In our analysis, real GDP per capita is represented by the letter A, ICT by the letter T, and CO2 emissions per capita by the letter I.

We update equation (3) to incorporate other explanatory factors (renewable energy, ICT, and some transmission canals) to provide greater flexibility in the analysis and to verify the validity of the influence of ICT on CO2 emissions in MENA nations.

To accomplish this, we consider the modified model that follows:

$$\begin{aligned} \ln CO_{it} = & \alpha_1 + \alpha_2 \ln GDP_{it} + \alpha_3 \ln GDP_{it}^2 + \alpha_4 \ln ICT_{it} + \alpha_5 \ln ICT_{it}^2 + \alpha_6 \ln RW_{it} + \\ & \alpha_7 \ln RW_{it}^2 + \alpha_8 \ln FDINV_{it} + \alpha_9 \ln TO_{it} + \alpha_{10} \ln FID_{it} + \alpha_{11} \ln RW * \ln ICT_{it} + \alpha_{12} \ln FDINV * \\ & \ln ICT_{it} + \alpha_{13} \ln TO * \ln ICT_{it} + \alpha_{14} \ln FID * \ln ICT_{it} + \varepsilon_{it} \end{aligned} \quad (4)$$

As indicated in the model, some factors can have an impact on the mitigation of climate change: renewable energy (RW), information and communications technology (ICT), the squared renewable energy (RW2), the squared ICT2, GDP, the squared (GDP2), trade openness (TO), financial development (FID), foreign direct investment (FDINV), and an interaction term between ICT and renewable energy (ICT*RW). The model incorporates connections between renewable energy and ICT on the one hand, and trade, financial development, and foreign direct investment on the other. The mild impact of each variable can be accurately represented by the coefficient associated with each interacting term.

The moderate impact of each variable can be accurately represented by the coefficient associated with each interacting term. The World Bank Indicators for the years 1990 through 2021 provide the data that we'll be using in this essay. This statistic pertains to the MENA countries. We use Pedroni's (1999) modified ordinary least squares (FMOLS) methods to get the panel long-run coefficients. This method can help with the endogeneity of the regressors, as well as the residuals' heteroskedasticity and autocorrelation.

3.3 Methodology

An overview of the estimating process for the FMOLS model can be found in the following four important elements. In the first phase, we determine whether cross-section dependence is present or not. Cross-sectional dependence (CSDP) is one of the primary issues that need to be settled before performing the empirical estimations of panel data. Estimated models are often erroneous with incorrect inference when dependency in the cross-sectional element generated by unobserved common characteristics in that data is not consistently addressed. We employ the test that Pesaran (2007) devised, which is regarded as the most reliable one.

Verifying whether or not each variable in the model is stationary is the second stage. We use the Pesaran test (URTP), one of the unit roots of the second generation of panel data (Pesaran, 2007). The main contribution of this generation above the tests of the previous generation is the explicit modeling of the interdependence among the panel members (countries). Our variables can only be

considered cointegrated if the series are I (1) at the level and become I (0) after their first variation. It should be noted that the previously described unit root test is only applied after it has been established whether or not cross-section dependence exists (Pesaran, 2007).

In the final phase, the panel cointegration analysis is guaranteed. To evaluate the cointegration hypothesis against the no cointegration linkages between variables hypothesis, we apply Pedroni's (1999, 2004) panel cointegration tests. When working with panel data, these statistics have the advantage of integrating heterogeneities and adjusting for endogenous variable bias. Calculating the long-run cointegration coefficients comes only after our variables have cointegrated.

Using modified ordinary least square (FMOLS) techniques developed by Pedroni (1999), we evaluate the panel long-run coefficients in the last stage. This method can help rectify the endogeneity of the regressors and the residuals' heteroscedasticity and autocorrelation.

4. Results and discussions

Table 2: CSDP and URTP tests

	CSDP	URTP	
		Level	1st difference
CO	8.123*** (0.000)	-1.642 (0.563)	-4.133*** (0.000)
GDP	7.064*** (0.000)	-1.234 (0.576)	-4.231*** (0.000)
ICT	8.445*** (0.000)	-2.723 (0.869)	-4.268*** (0.000)
RW	8.273*** (0.000)	-2.526 (0.776)	-3.442*** (0.000)
TO	7.663*** (0.000)	-1.546 (0.234)	-4.569*** (0.000)
FID	7.123*** (0.000)	-2.246 (0.669)	-3.236*** (0.000)

FDINV	8.623*** (0.000)	-1.236 (0.779)	-3.189*** (0.000)
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*significance at one percent is denoted by ****

Before to estimating the FMOLS model, it is imperative to assess the cross-sectional dependence of the variables used in our models (Pesaran , 2007).

As can be seen from Table 2, the Pesaran cross-sectional dependence test result is rejected.

Our variables may be tested using the Pesaran (2007) panel unit root test because they are expressed in levels and first differences. Table 2 illustrates how the variables previously discussed become stationary as a result of the initial difference change.

Table 3: Cointegration test

Statistics	T-statistics	P-Values
Within PP	--6.126***	0.000
Within ADF	-6.592***	0.000
Within Rho	-6.265***	0.000
Within V	-5.426***	0.000
Between PP	-6.123	0.000
Between ADF	-5.056***	0.000
Between Rho	-6.927***	0.000

*significance at one percent is denoted by ****

Table 5: FMOLS panel estimation

CO	Model 1	Model 1
GDP	0.022***	0.018***
	(0.000)	(0.000)
GDP²	-0.046	-0.056
	(0.416)	(0.613)
ICT	0.017***	0.011***
	(0.006)	(0.000)
ICT²	0.023	0.017
	(0.126)	(0.233)
RW	0.015	0.019
	(0.352)	(0.444)
RW²	0.017	0.010
	(0.423)	(0.312)
TO	0.153***	0.144***
	(0.000)	(0.000)
FDINV	0.125***	0.235***
	(0.000)	(0.000)
FID	0.053	0.049
	(0.127)	(0.221)
FW*ICT		-0.035***
		(0.000)
FID*ICT		-
		0.125***
		(0.000)
FO*ICT		-0.165***
		(0.000)

FDINV*ICT		-0.019*** (0.000)
cons	0.236*** (0.000)	0.358** (0.000)

Notes*** indicates significance at 1%.

Given that all of the variables are cointegrated (Pedroni's, 1999, 2004), Table 3's conclusions raise the possibility of a sustained link between them. Both within- and between-dimension tests are used to confirm this conclusion.

Next, we present the FMOLS panel model's long-term results (Table 4).

First off, CO₂ emissions are not affected by the usage of renewable energy sources because the parameters relating to RW and RW squared are negligible. This result is expected given that the MENA region consumes very little renewable energy and contributes to global oil and gas production. This result is at odds with the findings of Chen et al. (2022). These findings imply that, in order to improve environmental quality, the governments of the Middle East and North Africa (MENA) should give top priority to supporting policies and financial incentives that encourage investments in green technologies.

Second, whereas the ICT coefficient in the square form is negligible, it is positive and substantial in the level form. This outcome shows that ICT has worsened environmental conditions rather than improved them. This result implies that ICT goods and services are inefficient in the MENA region with regard to energy consumption. This result is in line with certain research conducted in developing and Asian nations (Khan et al., 2020; Arshad et al., 2020). This result seems fair and expected given the MENA region's economic composition and level of growth. To fully benefit from ICT's potential benefits on environmental quality, governments and policymakers must create and propose a variety of ICT policies based on the most recent developments in ICT tools and applications, such as blockchain technology and artificial intelligence.

Interaction variables between ICT and renewable energy use have been added to the model to help understand how the digital transformation enhances the influence of the energy transition on environmental quality. We find a negative interaction term in the results. This implies that the use of renewable energy leads to a reduction in CO₂ emissions for nations that have successfully completed the transition to digitalization. Emissions will be higher in nations that have struggled with the energy transition, though.

Since the GDP coefficient in the level form is positive and significant but it is insignificant and negative in the square form, the EKC hypothesis was not validated. This is to be expected because the MENA nations do not yet have the GDP levels necessary to improve the environment. Regarding 29 Asia-Pacific nations, our findings conflict with those of Khezri et al. (2022).

Fourth, given that the financial development variable has a modest coefficient, it appears that there is no direct relationship between financial development and environmental improvement in the MENA region. This could be caused by the underdeveloped banking and financial systems in the MENA area. However, it appears that financial development is indirectly supporting the digital transition when looking at the coefficients associated with the interaction term between financial development and technical innovation. Legislators should establish the funding structure required to fund R&D and technology expenditures in order to do this.

Fifth, trade has a discernible and positive effect on CO₂ emissions. One strategy to boost output and keep domestic businesses competitive in both domestic and foreign markets is trade openness. This outcome runs counter to what Khezri and colleagues (2022) found.

Sixth, foreign direct investment has a negative effect on environmental quality. Rising foreign direct investment will precede rising CO₂ emissions. This result makes sense given that the transfer of hazardous materials from developed to developing countries jeopardizes environmental sustainability and exposes them to climate change risks. Furthermore, high-caliber FI attracts low-tech enterprises, which explains its limited impact. This outcome agrees with Sarkodie and colleagues (2020). Finally, the model includes certain interaction terms between ICT on the one hand and trade, foreign direct

investment, and financial growth on the other to determine how digital transformation contributes to mitigating climate change through several channels. Negative interaction terms are displayed in the results. According to this research, the negative impacts of finance development, trade, and foreign direct investment on environmental quality may be lessened by the move toward digitization.

5. Conclusion and policy implications:

The principal objective of this article is to examine the relationship between environmental sustainability and the shift to renewable energy sources by explicitly integrating the digital mitigating factor. To accomplish this, we chose MENA countries from 1990 to 2021.

There are several policy ramifications for this research. First, environmental degradation is a result of economic expansion, and the MENA region has not yet attained the GDP threshold required to halt the trend. Therefore, the GDP of each nation must increase in order to attain the goal level.

Second, renewable energy has negligible effects on environmental quality. This suggests that environmental advancement is made possible by the usage of renewable energy in MENA countries. Therefore, governments should make more investments in renewable energy.

The third is that the quality of the environment is barely impacted by information and communications technologies. This suggests that the low adoption rate of ICT in MENA countries precludes any possibility of efficiency and technical improvements. Policymakers must spend money on information and communications technology to accomplish the digital transformation. Fourth, the combination of ICT and renewable energy can help reduce CO₂ emissions. Therefore, to hasten the energy transition, MENA countries had to concentrate on the achievement of digital transformation. Fifth, the shift to digital technology might lessen the detrimental effects of trade and foreign direct investment.

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