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Assessing the Relationship between CO_2 Emissions, Renewable Energy, Trade Openness and Economic Growth: MENA Countries Analysis

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ABSTRACT

This study employed the FMOLS and DOLS models to examine the impact of renewable energy, trade openness and economic growth on CO_2 emissions in MENA countries over the period 1990-2023. Furthermore, we employ SGMM approach in order to robustify DOLS and FMOLS results. Our findings reveal that the renewable energy promotes the environmental quality by decreasing the CO_2 emissions in the MENA countries. However, the economic growth increases the carbon emissions. The study reveals also that instead of the conventional U-shaped EKC hypothesis, there is the inversed U-shaped relationship between CO_2 emissions and economic growth in the long run. For the trade openness, it has a negative effect on CO_2 emissions, in the SGMM model. However, our findings in the FMOLS and DOLS show that it increases the CO_2 emissions in the long run. Then this paper suggests that MENA policy makers should maximise the use of renewable energy and ensure the efficient utilization of GDP and trade openness in order to minimise the level of CO_2 emissions.

Keywords: CO_2 Emissions, Renewable Energy, Trade Openness, Economic Growth

1. INTRODUCTION

Despite the importance of energy production and consumption in improving economic growth, they deteriorate the environmental quality by increasing carbon emissions (Charfeddine and Kahia, 2019), particularly with the use of non-renewable energies, namely fossil fuels, especially coal, gas and oil. Likewise, high energy costs create several economic problems, as well as increase the level of poverty. So, it is necessary to look for green energy sources. Indeed, according to the EIA (Energy Information Administration of USA) report, global energy demand will increase by 48% by 2040, which deteriorates environmental quality, particularly with the increase in the use of fossil fuels (Xing et al., 2023), hence the importance of research into other alternative and green energy sources. On the other hand, the massive use of non-renewable energies (fossil fuels) will limit the global energy supply in the future; for this reason, the search for renewable energies remains a necessity, particularly because of their low overall costs. However, their are lower than those of fossil fuels (Guo et al., 2023).

The MENA region has long been recognized for its vast oil and gas reserves, which have enhanced economic growth. However, the massive use of fossil fuels has increased carbon emissions, which deteriorate environmental quality (Zhu et al., 2016). Thus, to minimize CO_2 emissions, this region must transit to environmentally friendly and pollution-free economies, which requires the implementation of transition policies towards greener, low-carbon economies. So, MENA countries must put in place a combination of legislative and other technological policies that encourage, in particular, renewable energies.

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Also, the expansive economic growth of these countries as well as the rapid increase in carbon emissions have placed this region at a crossroads. Hence, climate change and sustainable development must be addressed in the MENA region.

Likewise, the increase in trade openness, particularly the increase in exports, improves the economic growth of MENA countries, in other words the increase in their GDP that increase the installation of industries that use polluting energies (Jun et al., 2020). Hence the environmental quality will be deteriorated by increasing CO_2 emissions (Wen and Chen, 2021).

So, a combination of challenges and unique perspectives of the MENA region make this study crucial. Indeed, these countries are characterized by enormous solar resources, a large desert territory and its expanding population requiring creative and context-specific solutions to balance economic growth and environmental protection.

In this context, we try in this research to examine the effect of renewable energies, trade openness and economic growth on CO_2 emissions in the case of MENA countries over the period 1990-2023.

Our contributions of this research can enrich the existing literature by bringing new perspectives to the authorities as follows: (1) This research work fills a gap by specifically evaluating the effectiveness of various policy initiatives by analyzing distinct factors such as renewable energy, trade openness, economic growth and CO_2 emissions during the period 1990-2023. (2) This study methodologically completes the literature by using the FMOLS, DOLS and system GMM (SGMM) methods. However, few previous studies have used these methods, particularly to test the long-term relationship between these variables in the case of MENA countries.(3) Our work could provide useful information to policymakers to mitigate environmental quality and propel the MENA region towards a sustainable, prosperous and resilient future.

The rest of the paper is organized as follows: Section 2 presents a review of the literature. Then, the document presents the model and the methodology in section 3 and defines the the empirical results and discussions in Section 4. Finally, Section 5 presents the conclusion and deals with policy implications.

2. LITERATURE REVIEW

2.1. CO_2-Economic Growth Relationship

When studying the CO_2-economic growth relationship, there is a very abundant literature. The EKC hypothesis is the most popular theory that links the effect of economic growth on the environment; this was the first empirical study by Grossman and Krueger (1995). The EKC theory shows that there is an inverse relationship between economic growth and pollution.

In this context, Niu et al. (2011) examined the long run relationship bteween energy consumption, GDP growth and CO_2 emissions for the eight Asia-Pacific countries. They concluded that exist a bidirectional causality between GDP growth and CO_2 in developed countries, however this causality is absent in developing countries. In addition, the authors confirmes the existence of a unidirectional causality runs from energy consumption to CO_2 emissions. Similarly, Narayan and Popp (2012) tested the environmental Kuznets curve (EKC) hypothesis for 93 countries over the period 1980-2004. They validated this hypothesis. Also, they showed the existence of a bidirectional causality between economic growth and pollution.

Furthermore, Mikayilov et al. (2017a) showed that there is a positive bidirectional causal relationship between energy consumption, CO_2 emissions, foreign direct investment and growth in the BRIC countries and Ukraine. Also, Mikayilov et al. (2017a) examined the impact of economic growth on air in Azerbaijan over the period 1990-2014 by applying the ARDL approach. They showed the existence of a positive relationship between these two variables.

Recently, Mohammadi et al. (2020) studied the relationship between economic growth, population and CO_2 emissions in Afghanistan during the period 1971-2016. Mohammadi et al. (2020) showed that population and GDP per capita are positively correlated with CO_2. More recently, Torun et al. (2022) studied the short and long run causal relationships between CO_2 emissions and economic growth for the case of US economy over the period 1980-2014. Torun et al. (2022) concluded that economic growth affect negatively the environmental quality. In addition, they showed the existence of a unidirectional long run causality between GDP and CO_2 running from GDP to CO_2 emissions.

2.2. Trade Openness-CO_2 Relationship

Several studies examined the relationship between trade openness and CO_2 emissions, since the 1990s especially with the rapid increase in trade openness and the gradual worsening of the environmental problem.

In this frame work, several researchs confirmed the existence of a positive relationship between trade openness and CO_2 emissions. In fact, employing a time series data in Pakistan over the period 1980-2010, Ali et al. (2015) showed that trade openness enlarge the size of production that harms air quality and ultimately worsens the environment by increasing the CO_2 emissions. Furthermore, Jun et al. (2020) showed that increasing the trade openness leads to anaugmentation in exports that intend to increase domestic production, especially, by improving industrial activity, which deteriorates the environmental quality. Recently, Jun et al. (2020) and Wen and Chen (2021) showed that trade openness has a positive impact on environmental deterioration.

However, other studies confirmed the existence of a negative relationship beteen trade openness and C2 emissions. In this context, Pazienza (2015) examined the impact of trade openness on CO_2 emissions in OECD countries. Pazienza (2015) conclude that trade openness negatively affects CO_2 emissions. Similarly, Cui et al. (2015) examined the relationship between trade openness and CO_2 emissions in United States. Cui et al. (2015) concluded that ameliorating trade openness will require businesses to adopt green technologies, So, CO_2 emissions decrease that ameliorate the environmental quality. Furthermore, Forslid et al. (2015) showed that trade openness will lead companies to expand their production scale, which will support more investments in reducing CO_2 emissions.

Recently, Ghazouani et al. (2020) showed that promoting trade openness ameliorates the environmental quality by reducing CO_2 emissions.

Finally, other economists have found mixed results between trade openness and CO_2 emissions. In fact, Baek and Kim (2011) found that the CO_2 emissions-trade openness relationship depends on the country's degree of development. However, this relationship is negative for the case of developed G-20 member countries, while it is positive for the case of developing member countries.

In addition, Jayanthakumaran et al. (2012) examined the impact of trade openness on CO_2 emissions. They showed a negative relationship between trade opennness and environmental quality in China. In contrast, they showed a positive relationship in the case of India. Also, Appiahkonadu (2013) studied the relationship between trade openness and CO_2 emissions in Ghana. He suggested that there are both positive effects (scale and composition effect) and negative effects (technical effect) of trade openness on CO_2 emissions, but the former is more important than the seconds.

Recently, Wang and Zhang (2021) found that the relationship between pollution and trade openness is positive for low-income countries, while it is negative for high- and middle-income countries.

2.3. Renewable Energy-CO_2 Relationship

Several studies have examined the impact of renewable energy consumption on CO_2 emissions because of the rapid increase in renewable energy consumption levels. In this framwork, several researchs confirmes the existence of a negative relationship between the consumption of renewable energies and CO_2 emissions.

Using US data, Baek (2016) showed that renewable energy consumption only has a negative impact on reducing CO_2 emissions in the short term. Furthermore, applying the FMOLS and DOLS approachs for 17 Economic Co-operation and Development (OECD) countries during the period 1977-2010, Bilgili et al. (2016) showed the existence of a negative relationship between renewable energy consumption and CO_2 emissions. Similarly, Aliprandi et al. (2016) examined the effect of installing renewable energy systems (e.g. wind and photovoltaics) on CO_2 emissions. They found that the reduction in CO_2 emissions is lower than expected given the amount of energy produced from RES and is linked to the level of RES penetration on the energy matrix.

In the same context, employing the ARDL model for the case of ten Latin American countries, during a period 1991-2012, Fuinhas et al. (2017) showed that renewable energies consumption reduces CO_2 emissions to −0.0415 and −0.1634 in the long run and the short term, respectively. In addition, Zoundi (2017) examined the impact of renewable energy consumption on CO_2 emissions and the environmental Kuznets curve (EKC) for 25 African countries over a period 1980-2012. Using the ARDL approach. Zoundi (2017) concluded the invalidity of the Kuznets curve. In addition, CO_2 emissions is positively affected by income, however it is negatively affected by renewable energy consumption.

Similarly, Jebli and Youssef (2017) amployed the cointegration model and Granger causality test in order to examine the relationship between renewable energy consumption, carbon dioxide emissions, gross domestic product (GDP) and agricultural value added (AVA) for a panel of five North African countries over the period 1980-2011. Jebli and Youssef (2017) concluded that there is a bidirectional causality between CO_2 emissions and renewable energy consumption at short term as well as long term. Also, they showed that renewable energy affects negatively the CO_2 emissions.

3. MODEL AND METHODOLOGY

To examine the relationship between CO_2 emissions, renewanle energies, trade openness and economic growth, our empirical analysis takes into account annual data for the case of the 18 MENA countries over the period 1990-2023. The model specification takes the following form:

$$CO2_{it} = \alpha_0 + \alpha_1 RE_{it} + \alpha_2 TO_{it} + \alpha_3 GDP_{it} + \alpha_4 GDP^2{}_{it} + \varepsilon_{it} \quad (1)$$

Based on the review of theoretical and empirical literature, we have highlighted the main determinants of CO_2 emissions. The independent variable of our model is CO_2 which implies CO_2 emissions (metric tons per capita). However, the explanatory variables are: RE refers consumption of renewable energies, it measured by the percentage of total final energy consumption); GDP refers the growth rate of GDP (annual %); GDP^2: This variable was introduced in order to take into account the possibility of non-linearity in the link between economic growth and CO_2 emissions, theoretically based on the Kuznet curve. TO: The degree of trade openness of the economy is measured by openness as a percentage of GDP.

Our research is based on a time series which we work on the case of MENA countries for the period from 1990 to 2023. The data used for the estimation of equation (1) are annual. They mainly come from the World Bank databases.

The paper examines the relationship between CO_2 emissions, renewable energies, aconomic growth and trade openness. First, we use the unit root tests in order to identify the presence of long-run characteristics in each variable. In this case, we use the Levin, Lin, and Chu (LLC) test and the Im, Peseran, and Shin (IPS) test.

Secondly, we employ the cointegration tests (Kao and Pedroni tests) in order to identify the presence of a long-run relationship among the variables with long-run characteristics.

Finally, the cointegrating equation estimations include the application of the DOLS and FMOLS approaches proposed by

Kao and Chiang (2001). We used these techniques to estimate and quantify the long-term relationship between variables. The first technique (DOLS) allows us to solve the endogeneity problem and eliminate the correlation found in the ordinary least squares (OLS) method. In fact, OLS estimation is inconsistent in cointegration panel series data (Dreger and Reimer, 2005). Furthermore, both estimation methods (DOLS and FMOLS) resolve the endogeneity problem and eliminate small sample bias.

Also, we apply the S-GMM method because it solves the endogeneity problem by introducing lags variable and thus it makes model dynamic. Also, this approach serves to robustify DOLS and FMOLS results.

Applying these approaches requires that all variables have the same order of integration and that the regressors should not appear to be cointegrated.

4. RESULTS AND DISCUSSION

4.1. The Long Run Relationship between CO_2, Renewable Energy, Trade Openness and Economic Growth

The unit-root properties are investigated by applying the Levin et al. (2002) t-test and Im et al. (2003) W-stat test. The results of unit-root tests are presented in Table 1. Our empirical findings show that all the variables are stationary in first difference. Thus, due to the same integrating order of all the series, it is appropriate to employ Pedroni's (2004) tests in order to test the existence of the long-run relationship among the variables. The results of this test are reported in Table 2. So, Regarding these findings confirm the existence of a cointegration relationship between the variables. For this reason, we will estimate our FMOLS and DOLS models.

The findings of the FMOLS and DOLS models are reported in Table 3. The coefficients estimated from these two models represent long-term elasticities. It is important to note that the coefficients estimated from the two FMOLS and DOLS models are very close and have the same signs.

Regarding renewable energy, its coefficients are negative and significant at 1% level in the FMOLS and DOLS models. So, we can point out that in the long term, renewable energy has a negative effect on CO_2 emissions in the region. The negative effect can be explained by the fact the renewable energy produce a green energy, so the pollution deceases. The results are in line with findings of Jebli and Youssef (2017) and Baek (2016).

For the control variables, the coefficients associated with economic growth have positive signs in the FMOLS and DOLS models. Indeed, the economic growth is positively and significantly correlated with CO_2 emissions 1% and 10% threshold in the FMOLS and DOLS models, respectively. The négative relationship between the two variables can be explained by the fact that when the economic growth is ameliorated, the government invest in the pollued industries, so the CO_2 emissions increase. So, we can say that the economic growth leads to environmental deterioration.

Table 1: Unit root test results

Variable	CO_2	RE	GDP	GDP2	TO
In level					
Levin, Lin and Chu t*	0.3655	0.6605	1.0000	0.9993	0.7691
Im, Pesaran and Shin W-stat	0.9981	0.1342	0.1564	0.9881	0.7584
First difference					
Levin, Lin and Chu t*	0.0000	0.0000	0.0000	0.0010	0.0000
Im, Pesaran and Shin W-stat	0.0000	0.0000	0.0000	0.0000	0.0001

Values in parentheses are P-values

*Statistically significant at the 10% level. **Statistically significant at the 5% level. ***Statistically significant at the 1% level

Table 2: Cointegration tests results

Test	Statistic	Prob.
Alternative hypothesis: Common AR coefs. (within-dimension)		
Panel v-statistic	−0.124191	0.5494
Panel rho-statistic	4.278983	1.0000
Panel PP-statistic	−2.219863	0.0132
Panel ADF-statistic	−1.648091	0.0497
Weighted		
Panel v-statistic	−3.065185	0.9989
Panel rho-statistic	2.671894	0.9962
Panel PP-statistic	−3.407391	0.0003
Panel ADF-statistic	−4.868171	0.0000
Alternative hypothesis: Individual AR coefs. (between-dimension)		
Group rho-statistic	4.655015	1.0000
Group PP-statistic	−4.902275	0.0000
Group ADF-statistic	−1.792402	0.0365

P-value in parenthesis *** and ** indicate the significance level at 1%and 5% respectively

Table 3: The long run effect of RE, TO and GDP on CO_2

Model	DOLS	FMOLS
RE	−0.510452	−0.510854
	(0.0000)***	(0.0000)***
GDP	0.004081	0.000939
	(0.0642)*	(0.0021)***
GDP2	−0.091156	−0.098131
	(0.0118)**	(0.0625)*
TO	0.000741	0.000750
	(0.0197)**	(0.0139)**
Adjusted R-squared	25.767442	29.162606
S.E. of regression	2.776995	2.945102
Long-run variance	0.008833	0.003528

*,**, and ***indicate significance at 10, 5, and 1% levels, respectively

In addition, regarding our results reported in Table 3, we conclude that the coefficient of the variable «GDP2» is negative and significant in the two models (FMOLS and DOLS). So, the empirical findings reveal that instead of the conventional U-shaped EKC hypothesis, there is the inversed U-shaped relationship between CO_2 emissions and economic growth in the long run. This means that the GDP has a positive a positive effect on CO_2 emmissions, however at a fixed threashold, this effect becomes negative.

For the coefficient of trade openness, it is positive and statistically significant at 5% level of significance in the FMOLS and DOLS models. The positive relationship can be explained by the fact when the amelioration of the trade openness helps countries to increase exports that ameliorate domestic production, by improving industrial activity, which leads to increased CO_2 emissions. The results are in line with the results of Jun et al. (2020) and Wen and Dai (2020).

4.2. Robustness of Results by Employing of SGMM Model

At the stade, we apply a dynamic model by employing the System GMM because it solves the endogeneity problem by introducing lags variable and thus it makes model dynamic. Also, this approach serves to robustify DOLS and FMOLS results.

In this Approach, the dependant variable is changed into the growth form. The consistency of the GMM estimator depends on the validity of instruments. To overcome this issue, it is necessary to use two specification tests: The first is the validity of Hansen's instruments and the second test consist in testing the validity of the second order autocorrelation.

The results of the SGMM are reported in (Table 4).

Findings reported in (Table 4) conclude that the two specifications tests do not reject the over-identification of Hansen and accept the null hypothesis of no second-order autocorrelation as well as the validity of the instruments. Also, we show that the estimation of our model (1) employing GMM system statistically and economically gives satisfactory results.

Our findings show that the coefficient of the lagged CO_2 emissions is positive and statistically significant at 10% level of significance. The empirical results confirm that current MENA CO_2 emissions depends on its previous level. In other words, the previous CO_2 emissions of the previous year represents an accumulation of pollution that leads to increase the CO_2 emissions of the current year.

Regarding the coefficient associated with renewable energy, it is negative and statistically significant at 1% threshold similarly for the FMOLS and DOLS models. These findings are in line with those found by Jebli and Youssef (2017) and Baek (2016).

Table 4: Results of estimation by GMM system method

Variable	SGMM
$CO_2(-1)$	0.215801 (0.0513)*
RE	−1.965001 (0.0001)***
GDP	1.235402 (0.0301)**
GDP2	−1.300251 (0.0021)**
OT	−1.009611 (0.0000)***
R-squared	0.960
AR (2)	0.289
Hansen test	0.598

*,**, and ***indicate significance at 10, 5, and 1% levels, respectively

Regarding the coefficient of the trade openness, it changes its sign compared to FMOLS and DOLS models. In fact, this coefficient is negative and statistically significant at 1%. So, we can say that the trade openness has a negative effect on CO_2 emissions in the SGMM model. This implies that an increased in trade openness, especially an decreasing in imports, ameliorate the environmental quality by decreasing the pollued products used in industrial activity and therefore decreases the CO_2 emissions.

For the economic growth measured by the GDP, it has the same effect of the FMOLS and DOLS models. However, for the GDP2, its coefficient negative and statistically significant at 5% level. The results reveal that instead of the conventional U-shaped EKC hypothesis, there is the inversed U-shaped relationship between CO_2 emissions and economic growth in the long run. This means that the GDP has a positive a positive effect on CO_2 emmissions, however at a fixed threashold, this effect becomes negative.

5. CONCLUSION AND POLICY IMPLICATIONS

At the end of our current research, it appears that the renewable energy decrease the CO_2 emissions. However, economic growth and trade openness increase the CO_2 emissions. In fact, we studied the relationship between renewable energy, economic growth, trade openness and CO_2 emissions for a sample of 18 MENA countries over the period 1990-2023. To do this, we used the FMOLS, DOLS and SGMM models.

The results show that renewable energie ameliorate the environmental quality in MENA countries by decreasing the carbone missions. However, economic growth and trade openness affect positively the CO_2 emissions in these countries. In addition, the empirical findings reveal that instead of the conventional U-shaped EKC hypothesis, there is the inversed U-shaped relationship between CO_2 emissions and economic growth in the long run. This means that the GDP has a positive a positive effect on CO_2 emmissions, however at a fixed threashold, this effect becomes negative. So, MENA policy makers should maximise the use of renewable energy and ensure the efficient utilization of GDP and trade openness in order to minimise the level of CO_2 emissions.

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