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Energy Consumption as a Measure of Energy Efficiency and Emissions in the MENA Countries: Evidence from GMM-Based Quantile Regression Approach

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ABSTRACT

Efficient efficiency of energy resources has been shown to have positive effects on both GDP growth and GHG emissions. While the negative effects of climate change and pollution continue to worsen, there has been a global slowdown in the rate at which energy efficiency (EE) is improving. In the Middle East and North Africa (MENA), carbon dioxide (CO_2) emissions can be considerably influenced by economic and energy consumption. Therefore, the purpose of this research is to apply the generalized method of moments based on a quantile regression approach to data for CO_2 emissions, EE, real income, and research and development in MENA from 1990 to 2021 in order to determine the factors that determine CO_2 emissions under the environmental Kuznets curve framework. Overall, the data showed that EE had a 3.2% impact on emissions reduction across all quantiles. In order to achieve their goals of lowering emissions and strengthening energy security, MENA states must increase the efficiency with which they use petroleum. EE policies may have rebound effects, which might reduce their efficiency, according to this study.

Keywords: Carbon Dioxide Emissions, Energy Efficiency, Environmental Kuznets Curve, GMMQR, MENA countries
JEL Classifications: Q54, Q43, Q51, B23, O57

1. INTRODUCTION

Preserving energy is a cornerstone of energy and environmental strategy meant to mitigate global warming's potentially disastrous effects. To attain the same level of performance while consuming less energy is the definition of energy efficiency (EE) (Niñerola et al., 2020). As a result, EE is essential for minimizing the cost of reducing Greenhouse Gases (GHGs) arising from energy consumption; nevertheless, accelerating EE gains calls for global initiatives in the adoption of EE measures. Wang et al. (2021) conducted a study that concluded that EE policies were still necessary to lessen environmental damage in the future. The potential for EE to spur economic development while simultaneously reducing emissions of GHGs is enormous. Concerns have been raised about the global slowdown in EE, which could have negative effects on consumers, economies, and the environment.

The major emitters of CO_2 in MENA during the past decade have been located in the Middle East and North Africa (MENA), including China and the United States. CO_2 emissions in MENA have decreased by 17% over the past decade, but this is not enough to offset the expansion of production in rising economies. The existing literature has numerous research that investigate how economic growth impacts ecosystems (Al-Mulali, et al., 2013; Ahmad, et al., 2020a; Jakada et al., 2020a; Jakada et al., 2020b; Farouq, et al., 2021). The environmental Kuznets curve (EKC) theory has been used in many of these researches to draw connections between economic development and environmental deterioration. This connection can take the form of a U or an inverted U depending on how the economy is doing. An inverted U-shaped model describes how income contributes to environmental degradation up to a tipping point, after which it begins to decrease pollution (Jakada et al., 2022a). U-shaped models, on the other hand, suggest an inverse connection between economic prosperity and environmental damage (Jakada et al., 2022b).

Governments around the world are struggling to find effective solutions to the problems posed by rising emissions and a warming planet. Rajak (2021), Nukusheva et al. (2021), Rehman et al. (2022), and others have proposed increasing the proportion of renewable energy in the energy mix as a means of mitigating the effects of climate change caused by carbon emissions. The Kyoto Protocol in 1997, the Paris Agreement in 2015, and the United Nations Conference in 2017 all show that numerous governments have given this subject their full attention. The events and their consequences have led to the development of significant legislation and practices aimed at mitigating climate change and other environmental threats. Goal 7 (Affordable and Clean Energy), 12 (Responsible Consumption and Production), and 13 (Climate Action) of the 2030 Sustainable Development Goals set by the United Nations are all directly relevant to the work being done here. In conclusion, this article examines the use of cleaner and more innovative energy sources (renewable energy) to maintain environmental quality in the MENA countries, as part of the implementation of SDGs. According to the World Bank (2020), MENA countries have a considerable reserve of natural gas and oil compared with other regions. These nations own 60% of the world's oil reserves and 45% of its natural gas reserves (BP 2018). On the other hand, most governments in the region devoted more attention to the energy policy and to spur more investments on renewable energy. According to the report of Asnani (2016), the share of renewable energy use out of total consumption in the Middle East is predicted to expand from 2% in 2010 to 12% by 2035. Recently, the COVID-19 epidemic has affected the energy sector severely as the demand on energy fell dramatically; this reduction lowered the oil prices. Lower global output of products and services, as well as a decline in the tourism sector, were two beneficial effects of the pandemic's duration. Green bonds are one example of the rising government investment in renewable energy (Oxford Business Group, 2020). According to MENA countries, the OECD (2020) addresses the strategies and methods to face COVID-19 crisis impacts. The paper indicated that governments of MENA nations have implemented various policies and strategies to promote the economy, enterprises, and households. As a corollary, the paper finds that the MENA region's energy industry has been crucial in enabling a wide range of services, such as the distribution of healthcare goods and the operation of offices located far apart. According to the paper, if MENA nations were to take measures to conserve energy, such as promoting the transition to cleaner energy sources, they could significantly cut down on carbon dioxide emissions and air pollution in the region. This study uses data from 1990 to 2021 to test the EKC theory's predictions about the impacts of economic growth, non-renewable and renewable energy consumption, and urbanization on CO_2 emissions in MENA nations.

This is the first attempt we are aware of to use the unique quantile regression approach proposed by Powell (2016) to analyze the impact of energy use on MENA economies. In addition to adding to the slender body of literature that employs quantile regression methods in the field, this study also contributes to the literature that focuses on the environmental impact of energy consumption by sources. The Methods section explains why this study chose to take this route. This research will aid regional policymakers in enacting effective and trustworthy legislation and laws to deal with the rising levels of pollution.

2. LITERATURE REVIEW

Carbon dioxide (CO_2) emissions have been an issue of discussion for the past decade. This contributes to the acceleration of global warming and a host of other environmental problems and dangers around the world. Because of this, research into the primary drivers of CO_2's beneficial and negative effects is essential. Increases in both the incidence of disease and mortality due to air pollution are predicted to occur at ever-increasing pollution levels. Due to this, many nations have made efforts to reduce their carbon footprint by increasing their usage of green power. CO_2 emissions in MENA countries have been the subject of numerous research (Bargaoui, 2021; Cheikh and Ben Zaied, 2021; Qasim et al., 2021; Lei et al., 2022). However, several studies in the academic literature have isolated the most significant contributors to air pollution (CO_2 emissions). Previous research indicated that the use of renewable energy sources provides a small amount of explanatory power for CO_2 in MENA nations. This suggests that MENA nations are still lagging behind in terms of environmental progress. (Usman et al., 2021) completed the most recent analysis of data from 13 MENA nations. This research looked at how the MENA region is affected by the use of both renewable and nonrenewable energy sources. The Augmented Mean Group method was used to calculate the data in this investigation. The study's main findings suggest that financial development, economic growth, and urbanization have had a favorable effect on reducing environmental deterioration. Surprisingly, the research showed that the use of renewable energy sources had no discernible effect on environmental quality, while the use of non-renewable energy sources considerably accelerated environmental degradation. Magazzino and Cerulli (2019) conducted research on 18 MENA nations between 1971 and 2013 to determine the correlation between carbon emissions, GDP, and energy consumption in the region. In this investigation, the responsiveness scores serve as the method of analysis (RS). The RS findings show a positive and statistically significant relationship between GDP per capita and energy usage.

In contrast, commercial activity and urbanization have a detrimental impact on CO_2 levels. Positive and negative factors of CO_2 emissions in MENA nations during 1990–2015 were uncovered in a study by Shahbaz et al. (2019). Generalized method of moments analysis was used to examine the data in this study (GMM). According to the GMM's findings, a country's level of economic growth (with its inverted U- and N-shaped model and its satisfaction of EKC assumptions), FDI, and biomass energy all have a significant and positive effect on the amount of carbon dioxide (CO_2) emissions it produces. Findings from this study strongly recommend that MENA countries should develop more efficient trade and energy usage rules and regulations. Charfeddine and Kahia (2019), on the other hand, look at the impact of renewable energy consumption and financial development on CO_2 emissions and economic growth for 24 MENA nations from 1980 to 2015. This study's findings suggest that measures of both CO_2 emissions and economic growth can be partially explained by measures of consumption of renewable energy and financial development. To better the environment and boost the economies of MENA countries, it is clear that the finance and renewable energy sectors need development. Additionally, Abdallh and Abugamos (2017) examined the EKC to determine the effect of urbanization on CO_2 emissions for 20 MENA countries between 1980 and 2014. Carbon dioxide emissions have been positively correlated with GDP per capita, total population, and energy intensity, but have shown no meaningful link with urbanization. Using the dynamic ordinary least squares (OLS) method, Al-Mulali et al. (2013) investigate the connection between energy consumption, urbanization, and CO_2 emissions for 20 countries in the MENA region between 1980 and 2009. The OLS results imply that higher rates of urbanization and energy demand over the study period led to greater environmental degradation. These results should serve as a wake-up call to authorities in MENA countries to curb the rate of urbanization and seek out other, less polluting energy sources (e.g., CO_2 emissions).

3. METHODS

3.1. Data

This research used the economies of the MENA to examine the impact of EE, economic growth, and research and development on carbon emissions (CO_2) in these regions: Algeria, Bahrain, Egypt, Ethiopia, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, United Arab Emirates, and Yemen. The data set used to evaluate these connections in time spans from 1990 to 2021. Emissions of carbon dioxide are the dependent variable, whereas EE, economic growth, and research and development are the independent factors. Table 1 showed a summary of the study's variables, including their definitions and their sources.

3.2. Estimation Techniques

Comparing the dynamic ordinary least square (D-OLS) method developed by Kao et al. (1999) with the fixed effect ordinary least square (FE-OLS) method was the focus of the current study. Standard errors developed by Driscoll and Kraay (1998) have been improved upon with the FE-OLS method. Furthermore, this statistical approach can withstand the presence of heterogeneity, dependence between sections, and autocorrelation (Ahmad, et al., 2018; Ahmad, et al., 2020b; Ahmad, et al., 2020c; Ahmad, et al., 2020d; Farouq, et al., 2020a; Farouq, et al., 2020b; Jakada and Mahmood 2020; Jakada et al., 2020a; Dabachi et al., 2020; Danmaraya et al., 2021). Specifically, we modify the panel framework of dynamic cointegration, mean difference within variations, and cross sections by introducing cointegration equilibrium in order to deal with the heterogeneity problem. Pedroni (2004) claims that the FMOLS can solve these issues. Monte Carlo simulations are being used to expand the panel options for D-OLS (Kao et al., 1999). To the contrary, when compared to other estimators, its objectivity shines through even with the limited size of the sample. D-OLS utilizes lag-and-lead differences to control for endogeneity. First proposed by Koenker and Bassett (1978), the panel quantile regression model was developed by the authors. By utilizing the values of the explanatory variables, the regression can evaluate the dependent's variance and conditional mean. Quantile regression provides more trustworthy results, even when the data includes outliers. Thus, we employed the MMQR technique proposed by Machado et al. (2019). The purpose of this statistical method is to evaluate the distributional and heterogeneous effects of using several quantiles. Here is an example of the location-scale variant conditional quantile estimates $Q\omega\ (\gamma/\varphi)$:

$$\omega_{it} = \sigma_i + \varphi_{it}^{'}\rho + \left(\tau_i + \delta_{it}^{'}\pi\right)L_{it}\,0.75em \quad (1)$$

3.3. Panel Causality Test

To determine the direction of causation between economic growth, EE, reaearch and development, and CO_2 emission in MENA nations, we employ the Dumitrescu-Hurlin (D-H) granger causality test. The ability to examine short-run causality independently is an appealing feature of this method (Jakada et al., 2022a; Jakada et al., 2022b; Jakada et al., 2022c; Kamalu et al., 2022). The following is an explanation of the estimation model:

$$\Delta LNCO_{2i,t} = \beta_i + \sum_{k=1}^{K}\partial_i^{(k)}\Delta LNCO_{2i,t-k} + \sum_{k=1}^{K}\gamma_i^{(k)}\Delta LNEE_{i,t-k} + \sum_{k=1}^{K}\delta_i^{(k)}\Delta LNRGDP_{i,t-k} + \sum_{k=1}^{K}\theta_i^{(k)}\Delta LNRD_{i,t-k} + \varepsilon_{i,t} \quad (2)$$

4. FINDINGS AND DISCUSSION

4.1. Descriptive Statistics and Correlation Matrix

Descriptive statistics on carbon dioxide emissions, EE, real gross domestic product, and research and development are reported in this study to facilitate comprehension of the data. Number of observations (23 nations * 31 years), mean, median, maximum,

Table 1: Description of the variables

Variables	Description	Unit	Source
$LNCO_2$	Natural logarithms of CO_2 emissions	CO2 emissions (kt)	International energy agency (IEA)
LNRGDP	Natural logarithms of gross domestic product per capita	GDP per capita (current US$)	World bank development indicator (WDI)
LNRGDP2	Natural logarithms of gross domestic product per capita square	GDP per capita (current US$)	World Bank Development Indicator (WDI)
LNEE	Natural logarithms of energy efficiency	Terawatt hour (TWh)	International energy agency (IEA)
LNRD	Natural logarithms of research and development on energy	Spending in millions	International energy agency (IEA)

minimum, kurtosis and skewness are all displayed in Table 2. When the results of skewness statistics are non-zero, it can be argued that the variables under study do not follow a symmetric and normal distribution. The kurtosis statistics are also larger than +3, indicating that the data have fatter tails than in a normal distribution (Ahmad et al., 2015a; Ahmad et al., 2015b; Ahmad et al., 2015c; Ahmad et al., 2015d; Ahmad et al., 2015e; Ahmad et al., 2015f; Umar et al., 2015; Hassan et al., 2016; Kamalu et al., 2019; Malam, et al., 2018; Alkhawaldeh et al., 2020; Ibrahim et al., 2020; Jakada, et al., 2020c; Jakada, et al., 2020d; Adam, et al., 2021; Atiku, et al., 2021; Umar, et al., 2021; Jakada, et al., 2020d; Atiku, et al., 2022; Jakada, et al., 2022d). Finally, descriptive statistics show that the data is heterogeneous, pointing to the panel quantile regression technique as the best bet for producing credible empirical results. The correlation matrix was reported in Table 3. The results revealed that the associations between the variables are less than 80% which indicated the absence of heteroskedasticity in the model.

4.2. Slope Homogeneity, Cross-sectional Dependency Test and Second-Generation Unit Root Tests

Before estimating the unknown parameters, this study did various preliminary tests to assess the qualities of the time series variables. We then investigate if the variables are homogeneous across nations and whether cross-sectional dependency (CD) occurs within the variables. Cross-sectional dependency may affect the real parameter values of coefficient estimations. When neglected, cross-sectional dependency caused by unobserved common factors dramatically reduces data-efficiency advantages (Phillips and Sul, 2003). As a result, considering the problem is critical for providing a reliable estimate of the coefficient. This study employed the Pesaran (2015) CD test to detect CD in the panel. In the model, all other quantitative factors in Table 4 show significant cross-sectional dependence. To address the issue, the unit root, cointegration tests, and estimating procedures for this model must include strategies that are resistant to CD concerns. The second-generation non-stationary unit root test of cross-sectional I'm Pesaran (CIPS) and cross-sectional augmented dickey fuller (CADF) were employed in this work to objectively investigate the integration features of the variables. These tests are used to investigate the extent to which cross-sectional dependence effects test results. Table 4 demonstrated that all variables in all root test specifications are non-stationary at levels, although they are stationary in the first difference. As a result, the variables of order one is integrated, I (1).

Table 2: Descriptive statistics

	$LNCO_2$	LNEC	LNRGDP	LNRD
Mean	10.58612	1.081062	4.062193	0.609828
Median	10.62497	1.081805	4.104307	0.410253
Maximum	13.36520	4.582315	12.73322	5.435620
Minimum	7.326466	–4.706945	–3.056581	0.019630
Std. Dev.	1.331096	2.325514	1.499976	0.847682
Skewness	–0.035070	-0.452105	0.244859	3.541599
Kurtosis	2.427257	2.663659	6.175904	15.91498
Observations	672	672	672	672

Table 3: Correlation matrix

	$LNCO_2$	LNRD	LNRE	LNRGDP
LNCO2	1.000			
LNRD	0.030 (0.429)	1.000		
LNRE	–0.612* (0.000)	0.008 (0.827)	1.000	
LNRGDP	0.379* (0.000)	0.152* (0.000)	–0.436* (0.000)	1.000

4.3. Panel Cointegration Test

Using the bootstrap method, this study may determine whether or not the variables have a long-run, non-spurious relationship by using Westerlunds' (2007) bootstrapped panel cointegration test. Pedroni (2004) proposed a comprehensive framework for assessing panel cointegration using Granger and 2-step Engle testing. To begin taking heterogeneity into account, the Pedroni test eliminates short-term patterns that are unique to individuals and determined by the parameters. Pedroni used a total of seven different test statistics, all of which are based on estimated residuals. These include both tests that assume a common process, also known as within-dimensional and pooled experiments, and tests that assume individual processes, known as between-dimensional or grouped tests. According to Table 5, the cointegration tests conducted using Pedroni (2004), Kao (1999), and bootstrap Westerlund (2007) all indicate that the null hypothesis of no long-run cointegration relationship should be rejected, indicating the existence of a cointegration relationship among the variable series. After establishing that a long-run cointegration nexus does, in fact, exist, we can go on to estimates of that nexus's long-run characteristics. Although it bears repeating, the cross-sectional dependence predicted by this model is present in the data. To account for this, we need to incorporate panel econometric approaches that are efficient, reliable, and robust to the effects of CSD in order to remove the potential size distortions from our panel estimation.

4.4. Estimation Results

Tables 6 displayed the results of the estimating process using DOLS, FMOLS, and FE-OLS. Statistical significance aside, Table 6 shows that all the average outcomes from the method are very near to one another. Income, EE, and research and development spending are the most constant variables across Table 6's coefficient scale and statistical significance. FMOLS results indicate that a percentage increase in income has a 29.5%

Table 4: Slope homogeneity and cross-sectional dependency and second-generation unit root tests

	Delta		CD-test	CIPS		CADF	
adj.	37.059* (0.000)	LNCO2	48.483* (0.000)	–2.133	–5.129*	–2.213	–3.737*
	40.345* (0.000)	LNRGDP	5.591* (0.000)	–2.173	–3.912*	–2.197	–3.162*
		LNRE	2.952** (0.003)	–0.786	–4.270*	–0.032	–2.826**
		LNRD	2.807** (0.005)	–1.182	–3.602*	–1.207	–6.972*

impact on CO_2 emissions. This agrees with Ponce and Khan (2021) but disagrees with Ozatac et al. (2017), who found that commerce had a positive and inelastic effect on carbon dioxide emissions. Furthermore, our FMOLS estimator finds that a square of national income (RGDP2) is a key factor in lowering CO_2 emissions. Using the FMOLS estimate, this comes out to a –2.6% decrease in CO_2 emissions for every 1% increase in GDP. The MENA region showed signs of a U-shaped curve, which we analyzed. Some prior investigations, including Tajudeen et al. (2018) and Fazli and Abbasi (2015), agree with this finding (2018). Thus, our findings support the EKC hypothesis, but they are at odds with the findings of Marques et al. (2019), who found that economic expansion enhances environmental deterioration in the MENA region. Although improved EE is expected to reduce carbon dioxide emissions, the estimated reduction might vary widely depending on the method used to measure it, from a decrease of 37.9% for the FMOLS estimator to an increase of 1% for the other methods. Despite Akdag and Yildirun (2020)'s finding that EE helps to alleviate environmental degradation in 66 developing economies, this study supports the conclusion that EE helps to reduce CO_2 emission in MENA. The FMOLS estimate confirms that investments in R&D lead to less environmental impact. An increase of 1% in R&D is predicted to result in a 3.3% reduction in CO_2 emissions, according to calculations by FMOLS. Wen et al. (2020) found a complicated association between research and development and environmental degradation in China, however our finding disputes that conclusion. In contrast, we found a negative correlation between R&D and environmental deterioration in France, Germany, Italy, and the United Kingdom, which is consistent with the findings of Wen et al. (2020).

In Table 7, we can see that the effect of square of real income on CO2 emissions is significant at the lower, middle, and upper quantiles, as estimated by the generalized method of moments (GMM) test. While a U-shaped association may exist at the lower quantiles, our research does not support its existence. To the contrary, the U-shaped theory is confirmed by the fact that the coefficient of square of real income became negative in the middle and upper quantiles. Degradation of the environment is worse at lower income levels in MENA, while it is less severe at higher income levels. DOLS, FEOLS, and FE-OLS all produced similarly reliable outcomes, demonstrating the methods' robustness. This finding substantiates the efficacy of environmental policies linked to GDP development in nations with high levels of pollution. In other words, MENA's average to above-average CO_2 emissions support the EKC hypothesis. Countries in the MENA that are more behind the average than the median in terms of development may put environmental quality lower on their list of priorities. The environmental impact is mitigated in the lower and upper quantiles by the EE coefficient in the DOLS, FEOLS, and FE-OLS estimators. This confirms the findings of Trotta (2020), who found an inverse correlation between EE and CO_2 emissions in Italy. However, these findings contradict the claims of Tajudeen et al. (2018) and Baiardi (2020), who argue that improving EE has no appreciable effect on ecological decline. We conclude that there is a negative and significant association between R&D and environmental deterioration based on our quantile, DOLS, FEOLS, and FE-OLS results. Cho and Sohn (2018) found an inverse correlation between R&D and environmental degradation in those four countries, and these results corroborate their hypothesis. Research and development also helped reduce environmental degradation in Malaysia, according to Yii and Geetha (2017). Wen et al. (2020) found a complicated association between scientific progress and environmental degradation in China, however our finding disputes that conclusion.

Table 5: Panel cointegration test

Westerlund (2007) bootstrap cointegration				
Statistics	**Value**	**Z-value**	**P-value**	**Robust P value**
G_t	–5.062*	–13.806	0.000	0.000
G_a	–17.633**	–2.501	0.006	0.009
P_t	–17.944*	–8.271	0.000	0.000
P_a	–16.746*	–4.243	0.000	0.000
Pedroni				
Statistic	3.665*			
P-value	0.000			
Kao				
Statistic	3.627*			
P-value	0.000			

Table 6: FMOLS, DOLS, and FE-OLS results

	LNGDP	LNGDP2	LNEE	LNRD
FMOLS	0.295*	–0.026*	–0.379*	0.033*
DOLS	0.125*	–0.089*	–0.225*	0.031*
FE-OLS	0.646*	–0.395*	–0.429*	0.085*

FMOLS: Fully modified least squares, DOLS: Dynamic panel least squares, FE-OLS: Fixed effect ordinary least square

4.5. Panel Causality Test Results

Table 8 empirical results demonstrate a causal relationship, in two-way directions, between EE and environmental degradation. Nonetheless, in the MENA region, there is a two-way causality connecting real income and CO_2 emissions. Additionally, this study discovered evidence supporting a causation both towards and away from EE and CO_2 emissions. The F-statistic for CO_2 in the EE function is statistically significant at the 5% level of significance, indicating a bidirectional causal link between EE and CO_2 emission. Since improving EE is so important in reducing

Table 7: GMM quantile regression test

	Lower quantile			Middle quantile			Higher quantile		
	0.10	**0.20**	**0.30**	**0.40**	**0.50**	**0.60**	**0.70**	**0.80**	**0.90**
LNGDP	0.111*	0.121*	0.133*	0.142*	0.155*	0.164*	0.168*	0.185*	0.216*
LNGDP2	0.061**	0.063**	0.066**	–0.068**	–0.070**	–0.073**	–0.074**	-0.077**	-0.083**
LNEE	–0.387*	–0.370*	–0.352*	0.336*	0.316*	0.302*	–0.293*	-0. 267*	-0.218*
LNRD	–0.041**	–0.027**	–0.014**	–0.007**	0.015**	0.026**	0.033**	0.053**	0.093**

GMM: Generalized method of moments

Table 8: DH-causality test

Direction of causality	W-stat	Zbar-stat	Prob.	Decision
$LNCO_2 \rightarrow LNRGDP$	8.359*	23.845	0.000	Bidirectional
$LNRGDP \rightarrow LNCO_2$	4.104**	10.057	0.020	causality
$LNCO_2 \rightarrow LNEE$	7.341*	20.546	0.020	Bidirectional
$LNEE \rightarrow LNCO_2$	11.884*	33.765	0.000	causality
$LNCO_2 \rightarrow LNRD$	10.145*	29.647	0.000	Bidirectional
$LNRD \rightarrow LNCO_2$	10.008*	29.189	0.000	causality

negative effects on the environment, this research has important policy implications.

5. CONCLUSION

This research empirically examined the interplay between EE, real income, research nd development, and CO_2 emissions in the MENA region. Over the course of 31 years, this study analyzed data from the MENA using second-generation panel unit roots, Pedroni, Kao, and Westerlund cointegration, dynamic panel least squares (DOLS), panel fully modified least squares (FMOLS), and generalized method of moments (GMM) quantile regression. The reduction of greenhouse gas emissions and the stimulation of economic growth are both possible outcomes of improved EE. However, progress toward greater EE has slowed in recent years. To lower their carbon footprints, MENA nations are exploring cheap and effective renewable energy options. The integration of our variables at order I(1), i.e. the existence of unit-root at level among complete variables, was confirmed by our cross-sectional panel unit root with Pedroni panel cointegration methods, as was the occurrence of CSD error among the variables. When it comes to the significance and relative sizes of the coefficients, the standard methods of estimating cointegration hold up well. Moreover, we used the GMM quantile regression method, which allows for the evaluation of different impacts exerted by exogenous variables in the study (EE, real income, R&D at different quantiles referring to conditional distribution for CO_2 emissions).

To make the empirical evaluation more reliable, FE-OLS and DOLS estimations were used. Validation of the EKC, or Kuznet's Inverted U-Hypothesis on Income for MENA, was achieved by the use of the coefficient estimates of FMOLS and FE-OLS (D-K-S-E). In the lower, median, and upper quantiles of our GMM Quantile Regression, as well as in the FE-OLS and DOLS estimators, we find that an increase in EE coefficients reduces environmental deterioration. Quantile-based estimates of economic growth, however, show a declining trend from the middle to the top quartiles. This data indicates that EE is high and CO_2 emissions are low, with the lowest CO_2 emissions found in the highest quantile. The influence is negligible in the lowest quantile, most likely because of the lower level of emissions in that quantile. If you want to see the most improvement in EE from your use of petroleum, solid fuels, and gas, you should aim for the maximum emission level. The impact of research and development is greatest at the highest quantiles of CO_2 emissions and least prominent at the lowest quantiles of emissions in MENA. This research categorized EE as using either solid fuels, petroleum, or gas, and displayed its effects in the highest, middle, and lowest emission quantiles, respectively. This research filled a gap in the literature by documenting the importance of petroleum EE in the MENA region. Research and development on a model to measure EE and environmental implications was also presented. The environmental performance of countries with higher emissions can benefit more from EE policies than low-emitting nations can. Companies that prioritize EE will not only use energy more effectively, but also reduce their energy consumption overall, freeing up more resources to be put into actual manufacturing and therefore boosting productivity. Because of this, it is important to support EE measures that aim to increase expenditures on projects with a low carbon emission footprint. To gain a deeper understanding of the phenomenon, researchers can focus their efforts on determining the monetary value of the impact on various stakeholder groups, as well as the effects of this monetization on investment decisions. The study's findings revealed that the MENA might enhance its environmental sustainability by lowering emissions and its energy security by reducing imports if it increased the efficiency of its petroleum products through moderate demand.

The study's authors advocated a policy to increase EE across MENA, particularly in the region's highest-emitting countries. Rebound effects may help explain why enhancing EE is not enough to stop environmental deterioration, and this should be taken into account in future studies. The paper's weakness lies in the fact that it only speculates on the possibility of a U-shaped pattern in the EKC framework for MENA nations, given their current levels of economic development. If economic growth in these nations accelerates, it might be worthwhile to conduct additional research into the possibility of observing an N-shaped relationship between them. Exploring the effects of COVID-19 on the shifting energy demand is another avenue to pursue in order to deepen the analysis. As a result of the closure of enterprises and a drop in air travel, energy consumption dropped sharply; but public transportation use dropped dramatically; and the production and environmental impact of surgical masks may have been substantial. Therefore, we anticipate that the added information will address the aforementioned issues.

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