Oil and natural gas rents and CO_2 emissions nexus in MENA: spatial analysis

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Background: Oil Rents (OR) and Natural Gas Rents (NGR) can increase emissions in the Middle East and North Africa (MENA), a natural resource-abundant region. Moreover, spatial autocorrelation is expected in CO_2 emissions due to the geographically closed economies in the MENA region. Thus, we examine the impact of OR and NGR on CO_2 emissions caring spatial dimensions and analyze the Environmental Kuznets Curve (EKC).

Methods: Because of the possibility of spatial linkages, we apply spatial techniques on the effects of OR, NGR, and economic growth on CO_2 emissions in 17 MENA nations from 2000-2019. Moreover, diagnostic tests are applied to reach the most appropriate spatial specification and to have the most robust results.

Results: The results disclose that CO_2 emissions have spillovers and emissions of any country can damage the environment of neighboring countries. The EKC is corroborated with a turning point of 38698 constant 2015 US dollars. Israel and Qatar are in 2nd phase of the EKC, and 15 MENA economies are found to be in the 1st stage. Thus, the economic expansion of most economies has ecological concerns. The effect of natural gas rents is found statistically insignificant. Oil rents have minute negative effects on emissions of local economies with an elasticity coefficient of -0.2117. Nevertheless, these have a positive indirect effect with an elasticity coefficient of 0.5328. Thus, the net effect of oil rents is positive. One percent increase in oil rents could accelerate 0.3211% of emissions. Thus, we suggest the MENA region diversify its economies from the oil sector to other unpolluted sectors.

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ABSTRACT

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Subjects Environmental contamination and remediation, environmental impact, spatial and geometric science
Keywords Oil rent, natural gas rents, CO_2 emissions, spillovers

INTRODUCTION

Most Middle East and North Africa (MENA) nations have huge oil and natural gas reserves in their economies and their income is heavily dependent on oil rents. For instance, the average oil rents during the period 2000-2019 are 21.22%, 16.16%, 23.19%, 48.24%, 46.42%, 47.24%, 34.87%, 25.86%, 38.39%, 20.24%, and 22.14% of Gross Domestic Product (GDP) in Algeria, Bahrain, Iran, Iraq, Kuwait, Libya, Oman, Qatar, Kingdom of Saudi Arabia (KSA), the UAE, and Yemen, respectively (World Bank, 2022). In the year 2020, 6 MENA economies are standing among the top 10 polluters in the globe as per CO_2 emissions per capita and are responsible for 8% of global CO_2 emissions (Global Carbon Atlas, 2022). As per the Paris Agreement, some MENA countries are expanding Renewable Energy Consumption (REC) to avoid non-REC, but the transformation is slow except for Morocco and Jordan. Moreover, most MENA countries have a miserable share of REC in the entire energy mix (Timmerberg et al., 2019).

The above discussion moves the attention to testing the impact of Oil Rents (OR) and Natural Gas Rents (NGR) on emissions in the high oil and natural gas-dependent MENA economies, but the MENA literature could not test this relationship so far. However, Al-Mulali (2011) analyzed and found the casual relationships between oil usage and CO_2 emissions. Moreover, some literature differentiated the impact of REC and non-REC on emissions. For example, some studies investigated the MENA panel and observed the positive impact of non-REC on emissions (Farhani & Shahbaz, 2014; Alharthi, Dogan & Taskin; 2021, Omri & Saidi, 2022). Moreover, the literature corroborated the negative impact of REC on emissions (Omri & Saidi, 2022; Kahia, Ben Jebli & Belloumi, 2019; Alharthi, Dogan & Taskin, 2021; Charfeddine & Kahia, 2019). Farhani & Shahbaz (2014) also substantiated the positive impact of REC on CO_2 emissions. Thus, the role of REC in reducing emissions is inconclusive. Moreover, some studies investigated and found the positive effect of aggregate Energy Consumption (EC) on emissions (Omri, 2013; Abdallh & Abugamos, 2017; Ekwueme & Zoaka, 2020; Al-Mulali et al., 2013).

The above-reported studies worked on EC variables, but studies did not explore the impact of Natural Resources Rents (NRR) on emissions. Resource rents are defined as the difference between revenues and cost of production of the resources (World Bank, 2022), which are supporting the income of resource-producing economies. Thus, oil and natural gas rents show economic dependence on these natural resources, and the production of such resources could have environmental consequences. This argument is supported by research on the MENA region by Abbass, Kumar & El-Gendy (2018). They explained that the overdependence on fossil fuel production could cause environmental damage as most of the emissions are flowing from the energy sector in the MENA region. The present study is different altogether from the MENA region literature, which could only focus on the role of the consumption of energy on emissions.

Moreover, the testing of NGR is scant in global literature. Thus, we contribute to both MENA and global literature.

To ensure an empirical contribution to the MENA literature, we include the spatial dimension in the relationship among OR, NGR, and CO_2 emissions. Because CO_2 emissions are global emissions and emissions from one country could also pollute the neighboring and surrounding countries. Thus, spillovers of CO_2 emissions cannot be ignored. Moreover, Bockstael (1996) strongly recommended doing spatial analyses in the ecological studies of a region due to the common landscape and dependent environmental and trading policies of a region. Thus, ignoring spatial dimensions in environmental studies in a region can produce biased results and misleading conclusions (Maddison, 2007), if a model statistically contains spatial autocorrelation (Anselin, Le Gallo & Jayet, 2008). Keeping in mind these arguments, the present study investigates the spatial effects of OR and NGR on CO_2 emissions in 17 MENA economies from 2000-2019. The maximum number of countries and time series from the MENA region are utilized as per the availability of data.

LITERATURE REVIEW

There is limited literature on testing the effects of NRR on pollution emissions. So, we discuss literature in three dimensions. The first dimension will cover the effect of NRR on emissions. The second dimension will discuss the environmental effects of the consumption of different energy sources. The third dimension will cover the literature on the MENA region.

We start with the literature on testing the effect of NRR on emissions. For instance, Ozturk (2017) investigated 9 Latin American economies from 1975-2013 by using seemingly unrelated regression and found that oil rents could not affect CO_2 emissions. Moreover, oil rents carried a positive relationship with economic progress in Ecuador and Venezuela and a negative relationship in Argentina. Moreover, nuclear energy increased economic progress in Colombia, Peru, and Venezuela. Bekun, Alola & Sarkodie (2019) analyzed EU-16 by using Pooled Mean Group (PMG) from 1996-2014 and found that NRR, non-REC, and economic expansion boosted CO_2 emissions and REC lowered them. Moreover, feedback effects were found between NRR and economic expansion and between REC, non-REC, and economic expansion.

Wang, Shahbaz & Ak (2020) explored G7 nations by using Autoregressive Distributive Lag (ARDL) technique from 1996-2017 and corroborated that globalization, Financial Market Development (FMD), and NRR increased CO_2 emissions. Nevertheless, agricultural activities lowered emissions. Danish (2020) explored the global economy from 1990-2013 by using ARDL and found that water productivity, NRR, and foreign trade increased CO_2 emissions. Moreover, the feedback effect was found between water productivity and emissions. Adedoyin et al. (2020) examined Brazil, Russia, India, China, and South Africa (BRICS) from 1990-2014 by using PMG and found surprising results that coal consumption and rents reduced CO_2 emissions and coal regulation increased CO_2 emissions.

Joshua & Bekun (2020) used ARDL and causality tests and found that coal consumption and economic expansion had feedback effects on each other in South Africa employing a period from

1970-2017. Moreover, NRR increased emissions. Agboola, Bekun & Joshua (2021) applied causality tests and discovered that EC, NRR, OR, and capital formation increased CO_2 emissions in KSA from 1970-2016. Nwani & Adams (2021) examined 93 economies and found that NRR boosted CO_2 emissions during 1995-2017 in countries having weak governance and reduced emissions in upper-high-governance economies. Tufail et al. (2021) probed OECD from 1990-2018 by using Cross-sectional Dependence (CD)-ARDL and found that fiscal decentralization and institutional quality helped to reduce CO_2 emissions. However, NRR and GDP increased emissions.

Considering spatial dimensions, Mahmood & Furqan (2021) probed Gulf Cooperation Council (GCC) economies from 1980-2014 by using Spatial Durbin Model (SDM) and found the EKC in CO_2, CH_4, N_2O, and Greenhouse Gas (GHG) emissions models. OR increased CO_2 and N_2O. FMD reduced all emissions and Foreign Direct Investment (FDI) reduced CO_2 and CH_4. EC increased CO_2 and N_2O. Moreover, all investigated variables showed spatial spillovers on the few investigated emissions. Shen et al. (2021) studied 30 Chinese provinces by using CD-ARDL and found that energy consumption, NRR, and FMD increased CO_2 emissions during 1995-2017. However, green investment reduced emissions. Huang, Sadiq & Chien (2021) examined the US by using quantile ARDL and found that NNR, FMD, and urbanization increased CO_2 emissions in most quantiles during 1995-2015. Moreover, the lags of all variables also significantly increased emissions.

Mahmood & Saqib (2022) analyzed 13 organization of the petroleum exporting countries from 1970-2019 in asymmetrical settings of nonlinear ARDL. The EKC was substantiated in 5 countries in the long term and 3 economies in the short term. Increasing OR increased CO_2 emissions in 8 countries and decreased emissions in 3 countries in the long run. Decreasing OR reduced CO_2 emissions in 4 countries and expanded emissions in 1 country. In the short-term results, increasing OR increased CO_2 emissions in 4 countries and decreased emissions in 2 countries. Moreover, decreasing OR lowered CO_2 emissions in 4 countries. Royal, Singh & Chander (2022) investigated G7 countries from 1971-2019 employing Fully Modified Ordinary Least Square (FMOLS) and found that oil prices and rents increased REC in the panel. However, FDI could not encourage REC. Saqib, Duran & Hashmi (2022) explored the GCC countries from 1993-2019 by using CD techniques and stated that economic expansion, NRR, and non-REC increased emissions. Financial deepening and REC reduced CO_2 emissions. The EKC was not validated.

Huang & Guo (2022) explored 30 Chinese provinces from 1995-2017 by using ARDL and found that NRR, transportation, innovation, FMD, and energy investment increased carbon emissions. Gyamfi (2022) investigated Sub-Saharan Africa from 1990-2018 by using CD techniques and found that FDI, economic expansion, NRR, and urbanization increased consumption-based emissions. Adebayo et al. (2023) showed in their paper that many factors including REC, NRR, and technological innovation had a critical role to play in BRICS CO_2 emissions trends. They used data from 1990-2019 and applied the ARDL model. The results showed that over a long period, technological innovations help reduce emission levels. Additionally, REC and NRR reduced these emission levels. Technological innovation interacting with the other two variables of REC and NRR also reduced pollution in the region. Their analysis showed crucial policy implications in order to control emission levels by investing in more technological development and related factors.

After discussions on the environmental effects of NRR, we exhibit literature on the effects of various energy sources on emissions. Lim, Lim & Yoo (2014) analyzed the Philippines from 1965-2012 by using causality analysis and found feedback between oil usage and CO_2 emission and between oil usage and economic expansion. Alkhathlan & Javid (2015) analyzed KSA and substantiated that aggregate oil and transport oil usage accelerated CO_2 emissions during 1971-2013. Moreover, economic expansion and its square increased CO_2 emissions in a nonlinear analysis. Bildirici & Bakirtas (2016) examined BRICS and Turkey from 1969-2011 by using ARDL and found that coal and oil usage caused CO_2 emissions. Moreover, the feedback effect between both energy sources and emissions was reported.

Mensah et al. (2019) analyzed twenty-two African countries from 1990-2015 by using CD techniques and found the feedback effects among fossil fuel use, emissions, and economic expansion. Moreover, oil prices also caused fossil fuel use, emissions, and income. Saboori, Rasoulinezhad & Sung (2017) investigated 3 economies from 1980-2013 employing a cointegration test and found that oil usage caused South Korean emissions and caused economic expansion in China and Japan. Szetela et al. (2022) examined the 10 resource-rich economies from 2000-2015 and found that REC reduced CO_2 emissions with a condition of good governance in the countries. Moreover, the EKC was also validated.

Mahmood (2022) examined GCC economies by using nonlinear ARDL and stated that oil and natural gas usage boosted CO_2 emissions during 1975-2019. The environmental influence of oil usage was found to be more than natural gas. Belucio et al. (2022) studied Europe from 1993-2018 by using ARDL. They stated that both oil and natural gas usage raised CO_2 emissions. The coefficient of oil consumption on emission was found to be less than 1, which indicated the energy efficiency gains. Moreover, the effect of oil consumption was found to be 6.7 times greater than natural gas and REC reduced CO_2 emissions. Aslam et al. (2022) investigated Malaysia from 1971-2016 by using ARDL and found that liquid fuel consumption, trade openness, industrial sector, and economic performance increased CO_2 emissions. Moreover, a feedback effect was reported between liquid fuel usage and trade.

There is no research investigating the impact of NRR on emissions in MENA panel. However, we discuss the studies considering the impact of EC and other macroeconomic factors on emissions in the MENA panel. For instance, Al-Mulali (2011) investigated the MENA economies from 1980-2009 and found feedback among oil usage, CO_2 emission, and economic expansion. Omri (2013) examined 14 MENA countries from 1990-2011 by using a causality test and found the feedback effect between economic expansion and emissions. Moreover, a two-way causality was reported in EC and economic expansion. However, the one-way effect is reported from EC to CO_2 emissions. Al-Mulali et al. (2013) probed the MENA region from 1980-2009 by using a causality test and found that urbanization and energy consumption shared feedback effects with CO_2 emissions in the region.

Farhani & Shahbaz (2014) investigated 10 MENA economies from 1980-2009 by using FMOLS and substantiated the EKC. Moreover, both REC and non-REC accelerated CO_2 emissions. Abdallh & Abugamos (2017) probed 20 MENA economies from 1980-2014 by using semi-parametric techniques and found that urbanization had a minute impact on emissions in nonlinear analyses. Moreover, economic expansion and energy consumption were responsible for higher emissions. Charfeddine & Kahia (2019) examined used cointegration and found that REC and FMD had a minute effect on emissions in 24 MENA economies from 1980-2015, which showed a weak position of these economies to have pleasant environmental effects from REC and FMD. Kahia, Ben Jebli & Belloumi (2019) studied 12 MENA economies from 1980-2012 by using cointegration and causality analyses and found that economic expansion increased CO_2 emissions while REC, foreign trade, and FDI helped reduce CO_2 emissions. Ekwueme & Zoaka (2020) investigated 10 MENA countries from 1970-2017 and found that FMD decreased the effusion of CO_2 emissions. Nevertheless, trade openness and EC raised the effusion of CO_2 emissions.

Alharthi, Dogan & Taskin (2021) employed quantile regression and found that REC reduced CO_2 emissions and its effect increased over higher quantiles in the MENA region from 1990-2015. Non-REC increased CO_2 emissions and its effect was decreased over higher quantiles. The EKC was also confirmed in the region. Ben Cheikh & Ben Zaied (2021) examined the MENA region by using threshold regression and found that income reduced emissions, which was due to changing energy mix towards renewable and low-carbon technologies. Omri & Saidi (2022) investigated 14 MENA economies by using FMOLS and found that REC reduced CO_2 emissions and non-REC and industrial sectors accelerated CO_2 emissions. Moreover, a feedback effect was stated among non-REC, REC, and emissions and between the agriculture sector and CO_2 emissions.

Some literature could not include energy variables but tested the effect of other macroeconomic variables on emissions. Guoyan et al. (2022) analyzed the MENA region by using Panel Smooth Transition Regression (PSTR) and found that FDI helped in minimizing CO_2 emissions during 1995-2016. Ben Lahouel et al. (2022) explored 16 MENA economies from 1990-2019 by using PSTR and found that information technology could help reduce CO_2 emissions after a threshold point. Gorus & Aydin (2019) examined 8 MENA economies from 1975-2014 and could not find any indication of causality between economic expansion and CO_2 emissions. Thus, economic growth did not be achieved at a level to support CO_2 emissions reduction. Sinha et al. (2020) probed MENA economies from 1990-2017 by quantile-on-quantile regression and found feedback effects between technological progress and ambient air pollution.

The reviewed literature finds a positive impact of NRR on emission in most studies. However, the negative effect of NRR is also corroborated by a few studies. Thus, the testing of the effect of NRR on emissions is an empirical question for any country or region and the present research is an effort to examine this question in the MENA region, which is absent in the present MENA literature. Moreover, aggregate NRR is mostly explored in the literature, and testing the effect of NGR is scant. Thus, we investigate the separate effects of OR and NGR on emissions to ensure a contribution to the globe and MENA literature.

METHODS

The goal of this research is to assess the role of economic growth, OR, and NGR on CO_2 emissions in resource-abundant MENA economies. Here, we cannot ignore the testing of the EKC, which explains the nonlinear effect of economic expansion on emissions (Grossman & Krueger, 1991). Meadows et al. (1972) claimed that the excessive use of natural resources could limit global growth as natural resources are limited on the globe. Moreover, Auty (1985) did a pioneer study in this context, which corroborated an inverted U-shaped connection between economic expansion and metal use. Moreover, natural resources would accelerate emissions because energy and natural resources consumption would be used at the same rate in an early phase of growth (Dinda, 2004). Thus, OR and NGR would release emissions in the oil and natural gas-rich MENA countries. So, the present research adds both variables of OR and NGR in the model to test the EKC and the basic model is as follows:

$$CO2_{it} = f(Y_{it}, Y_{it}^2, OR_{it}, NGR_{it}) \quad (1)$$

$CO2_{it}$ is the natural log of per capita CO_2. Y_{it} is a natural log of per capita GDP (constant 2015 US \$). Y_{it}^2 is the square of Y_{it}. The quadradic effect of economic growth is included in a model to examine the EKC hypothesis. OR_{it} and NGR_{it} are the percentages of oil rents and natural gas rents in GDP, respectively. These variables are not converted in logarithms as both are already in percentages. Data from 17 MENA countries during 2000-2019 are obtained from World Bank (2022) on variables mentioned in equation 1. Country and time sample is selected based on data availability.

Equation 1 will be estimated by using the Fixed Effects (FE) model and the Likelihood-Ratio (LR) test will be applied to check the appropriateness of FE over pooled regression to check the most suitable model specification. Thereon, Lagrange Multiplier (LM) and LM robust tests will be utilized to test the possible spatial autocorrelation (Debarsy & Ertur, 2010). In pollution-related studies, spatial dimensions are expected (Bockstael, 1996). It is particularly important for the MENA region as it is sharing almost the same landscape and most countries in it are neighboring as well. Secondly, CO_2 emissions are global emissions and CO_2 emissions in one country could affect the ecology of neighboring or nearby countries. If spatial autocorrelation is found significant in statistical findings, then SDM is suggested to be applied to capture the spillovers (Elhorst, 2012). The SDM of equation 1 can be presented as follows:

$$CO2_{it} = \alpha_0 + \alpha_1 Y_{it} + \alpha_2 Y_{it}^2 + \alpha_3 OR_{it} + \alpha_4 NGR_{it} + \beta_1 W.Y_{it} + \beta_2 W.OR_{it} + \beta_3 W.NGR_{it} + \delta W. CO2_{it} + v_i + u_t + w_{it} \quad (2)$$

W is a 17*17-dimension matrix to capture the effect of distance between MENA countries. Kelejian & Prucha (2010) suggested a method to normalize W to have robust results and to capture spillovers of CO_2 emissions in neighboring countries. Thereafter, Elhorst (2010) recommended the Wald test to verify the best spatial specification. A null hypothesis (H_{01}) of $\beta_j = 0$ will be tested to verify whether SDM tends to be converted to Spatial Autoregressive (SAR) specification or not. In the same way, H_{02} of $\beta + \delta.\alpha = 0$ may also be tested to confirm the validity of SDM over the Spatial Error Model (SEM). The rejection of both may verify that the SDM is the best choice. Otherwise, the estimations may move toward SAR or SEM specifications.

RESULTS AND DISCUSSION

We start with discussions of the spatial distribution of CO_2 emissions and oil and natural gas rents. Figure 1 shows the spatial distribution of oil rents percentage of GDP and an average of years 2000-2019 in 17 MENA countries. Israel and Jordon are neighboring countries having oil rents less than 1% of GDP. Egypt, Syria, and Tunisia are nearby countries having oil rents between 1-9.9% of GDP. Bahrain, Iran, Qatar, and the UAE are neighboring countries having oil rents between 10-29.9% of GDP. Iraq, Kuwait, Oman, and Saudi Arabia are neighboring countries having oil rents of more than 30% of GDP. Thus, figure 1 shows the spatial linkages in terms of oil rents in MENA countries.

Figure 2 shows the spatial distribution of natural gas rents percentage of GDP and an average of years 2000-2019. Iraq, Israel, Jordon, Kuwait, Saudi Arabia, and the UAE are neighboring countries having natural gas rents less than 1% of GDP. Moreover, Morocco and Tunisia are nearby countries with a similar range of natural gas rents. Egypt and Libya are neighboring countries having natural gas rents between 1-1.9% of GDP. Bahrain, Iran, and Oman are nearby countries having natural gas rents between 2-2.9% of GDP. Hence, figure 2 shows the spatial linkages in terms of NGR in MENA countries.

Figure 3 demonstrates the spatial distribution of CO_2 emissions per capita average for the years 2000-2019. Algeria, Egypt, Iran, Iraq, Israel, Jordan, Libya, Syria, and Tunisia are mostly neighboring countries and are located on a horizontal script in the map having CO_2 emissions between 2-9.9 metric tons per capita. Oman and Saudi Arabia are neighboring countries having CO_2 emissions between 10-19.9. Bahrain, Kuwait, Qatar, and the UAE are neighboring countries having CO_2 emissions of more than 20. Thus, figure 3 shows the spatial linkages in CO_2 emissions in MENA countries.

Table 1 exposes the results of FE without spatial dimensions. At first, we apply the LR test on FE and the results reject the H_0 for FE-country and FE-both specifications. So, both are valid and superior over pooled regression. However, the LR test could not reject H_0 for FE-time. Thus, it is not a valid specification. In both FE-country and FE-both, the EKC is substantiated by the positive and negative parameters of Y_{it} and Y_{it}^2, respectively. Moreover, oil rents are decreasing CO_2 emissions in FE-both estimation and have insignificant effect in the FE-country model. Moreover, natural gas rents have insignificant effects in FE-country and FE-both models. Hereafter, we apply LM and LM robust tests as figures 1-3 show the spatial linkages, which reject the H_0 in all models. Thus, FE models are biased as spatial autocorrelation is substantiated in all models. Thus, we switch to the SDM estimation.

For completeness, we estimate SDM in FE and Random Effects (RE) with country and time effects. Then, we apply LM and LR tests on both models to test the suitability of the SDM. In table 2, both tests reject H_{01} and H_{02} in both models, which indicates that SDM cannot reduce to SAR or SEM. Thus, SDM is the most suitable model specification. Afterward, the Hausman test is applied and H_0 is rejected. Thus, SDM with FE specification may be preferred over RE and this model is chosen for interpretation.

In SDM with FE specification, we ignore the interpretation of point estimates, which do not carry spatial effects. In the direct estimates, the parameters of Y_{it} and Y_{it}^2 are positive and negative, respectively. The EKC is corroborated in the local economies of the MENA region. Moreover, oil rents have a negative impact with a coefficient of -0.2117. Thus, 1% increase in OR_{it} is reducing emissions by 0.2117%, which is a minute effect. Thus, oil rents are helping to reduce CO_2 emissions, but the local MENA economies are not mature enough in reducing CO_2 emissions at a large scale. The effect of NGR_{it} is noticed as statistically insignificant. Thus, NGR does not help reduce CO_2 emissions. However, these are not at least increasing CO_2 emissions. Thus, its environmental effect is neutral. This result corroborates the fact that oil rents are significantly higher than natural gas rents.

In the indirect estimates, economic growth substantiated a U-shaped impact on CO_2 emissions with the negative and positive coefficients of Y_{it} and Y_{it}^2, respectively. The EKC is not substantiated by the spillover effects. OR_{it} carries a positive impact with a coefficient of 0.5328 and 1% increasing OR_{it} is increasing emissions by 0.5328% in neighboring countries. Moreover, the spillover coefficient is greater than the direct effect coefficient. Consequently, the net impact of OR_{it} is increasing CO_2 emissions in the MENA region. The spillover effect of NGR_{it} is statistically insignificant. Thus, NGR_{it} has no environmental spillover on the CO_2 emissions of neighboring countries. Moreover, the parameter of $W*CO2_{it}$ is positive. Thus, increasing CO_2 in a MENA country is responsible for increasing emissions in neighboring economies as well.

In the total estimates, the coefficients of Y_{it} and Y_{it}^2 are 2.3768 and -0.1125, respectively. The EKC is corroborated in the whole region, which is also substantiated by previous MENA literature (Farhani & Shahbaz, 2014; Alharthi, Dogan & Taskin, 2021). The turning point of this shape is approximately 38698 constant 2015 US dollars ($e^{2.3768/2/0.1125}$) and Qatar and Israel are found in the 2nd phase. Israel is not much dependent on OR and NGR. Qatar has achieved the top per capita GDP among the MENA countries. Thus, economic expansions have pleasant environmental outcomes. However, Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Libya, Morocco, Oman, Saudi Arabia, Syria, Tunisia, the UAE, and Yemen are still in 1st phase of the EKC, and their economic expansions have environmental concerns. OR_{it} has a positive effect with a coefficient of 0.3211. So, 1% increasing OR_{it} is raising emissions by 0.3211% in the whole MENA region. Thus, increasing OR has environmental damage for the whole region. This finding of the OR effect is also supported by Agboola, Bekun & Joshua (2021) in KSA, Mahmood & Furqan (2021) in GCC, and Mahmood & Saqib (2022) in OECD. The effect of NGR is statistically insignificant. Thus, NGR does not affect the environment of the MENA region.

CONCLUSION

The MENA countries are OR- and NGR-abundant economies, which would damage the environment. Moreover, these are geographically nearby countries, and their pollution emissions could have spillovers on each other. Thus, the present study investigates the EKC and the effects of OR and NGR on CO_2 emissions in the MENA region by using SDM. The results show that CO_2 emissions have spatial autocorrelation and these global emissions of one country are also damaging the environment of their nearby MENA countries. Moreover, the EKC is substantiated with a turning point of 38698 constant 2015 US dollars. Israel and Qatar are found in 2nd stage of the EKC, and their economic expansions are helping in the reduction of CO_2 emissions. However, the rest 15 MENA economies are found to be in the 1st stage and their economic growth has environmental concerns. OR has a minute negative impact on emissions in local economies with an elasticity coefficient of -0.2117. However, the spillovers of oil rents are positive and damaging the environment with an elasticity of 0.5328. Thus, the net effect of oil rent is damaging the environment in the region and 1% increase in oil rents is releasing 0.3211% of CO_2 emissions. The effect of NGR is statistically insignificant. Thus, NGR has neither positive nor negative effects on the environment of the MENA region. The results suggest the MENA region reducing reliance on oil rents, which is possible by adopting the diversification policy from the oil sector.

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ADDITIONAL INFORMATION AND DECLARATIONS

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Competing Interests

Haider Mahmood is an Academic Editor for PeerJ.

Author Contributions

Haider Mahmood conceived and designed the experiments, performed the experiments,

analyzed the data.

Najia Saqib, Anass Hamadelneel Adow, and Haider Mahmood prepared figures and/or tables and wrote the original draft.

Muzafar Abbas reviewed drafts of the article and approved the final draft.

Data Availability

The following information was supplied regarding data availability:

The raw data are available in the Supplemental Files.

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Figure 1

OR percentage of GDP average of years 2000-2019

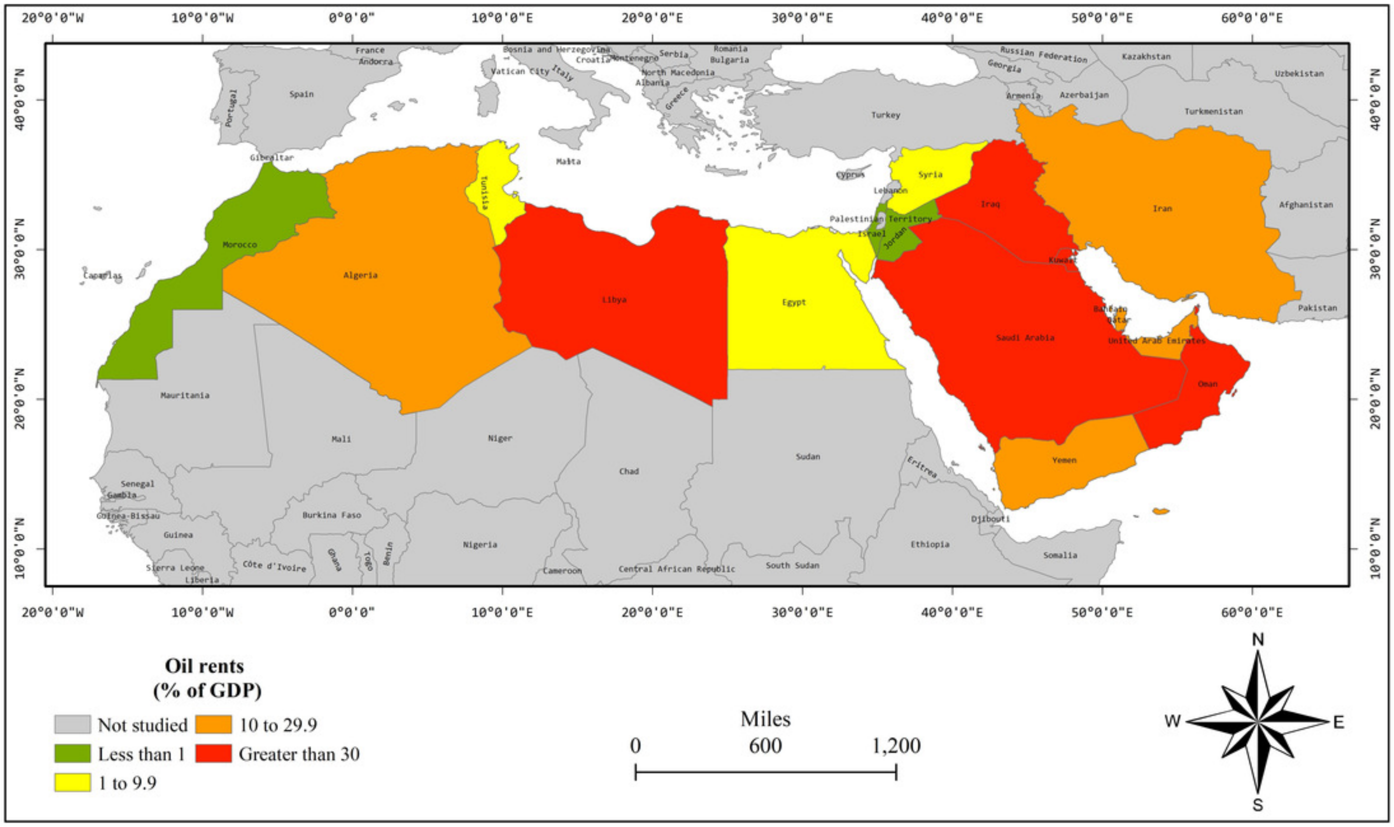

Figure 2

NGR percentage of GDP average of years 2000-2019

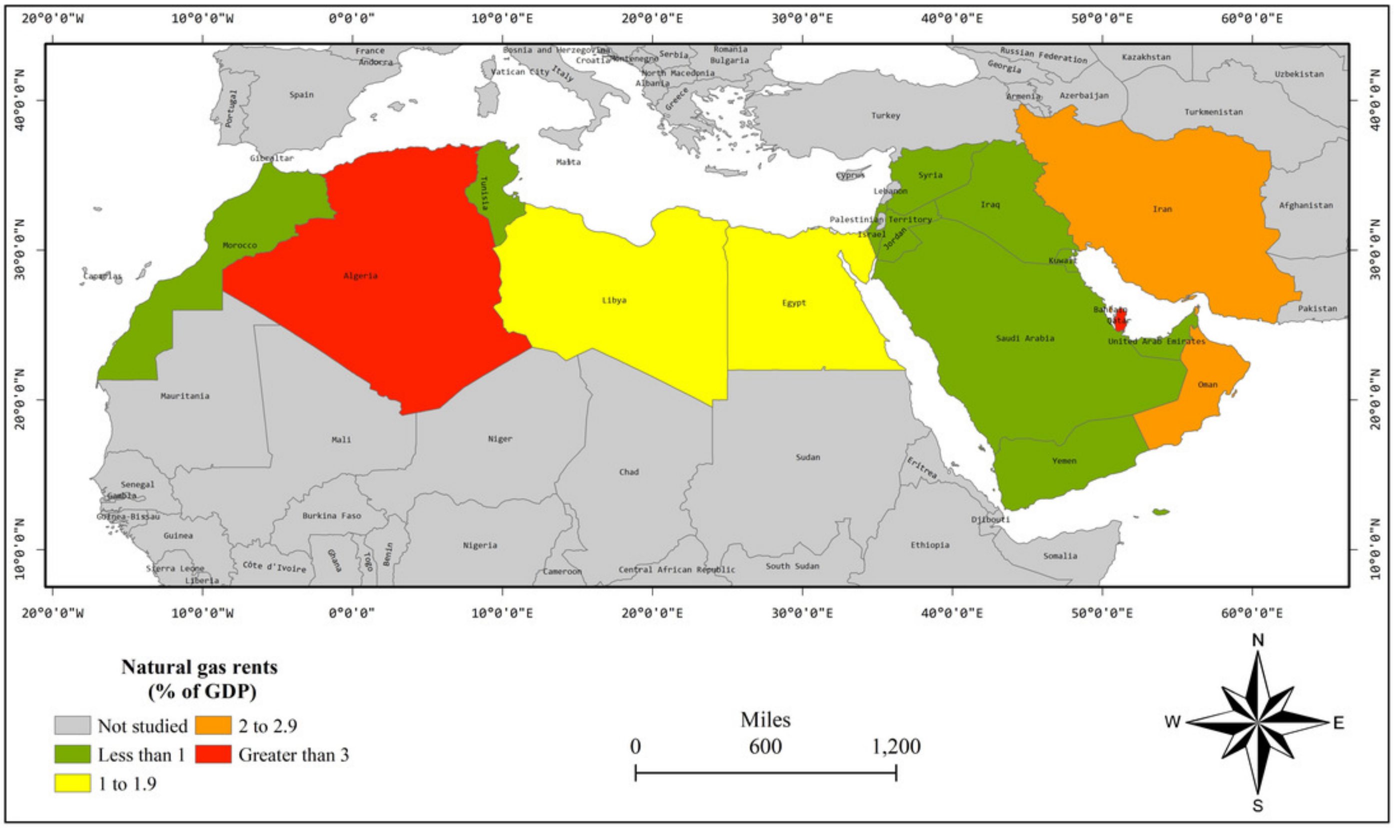

Figure 3

CO_2 emission per capita average of years 2000-2019

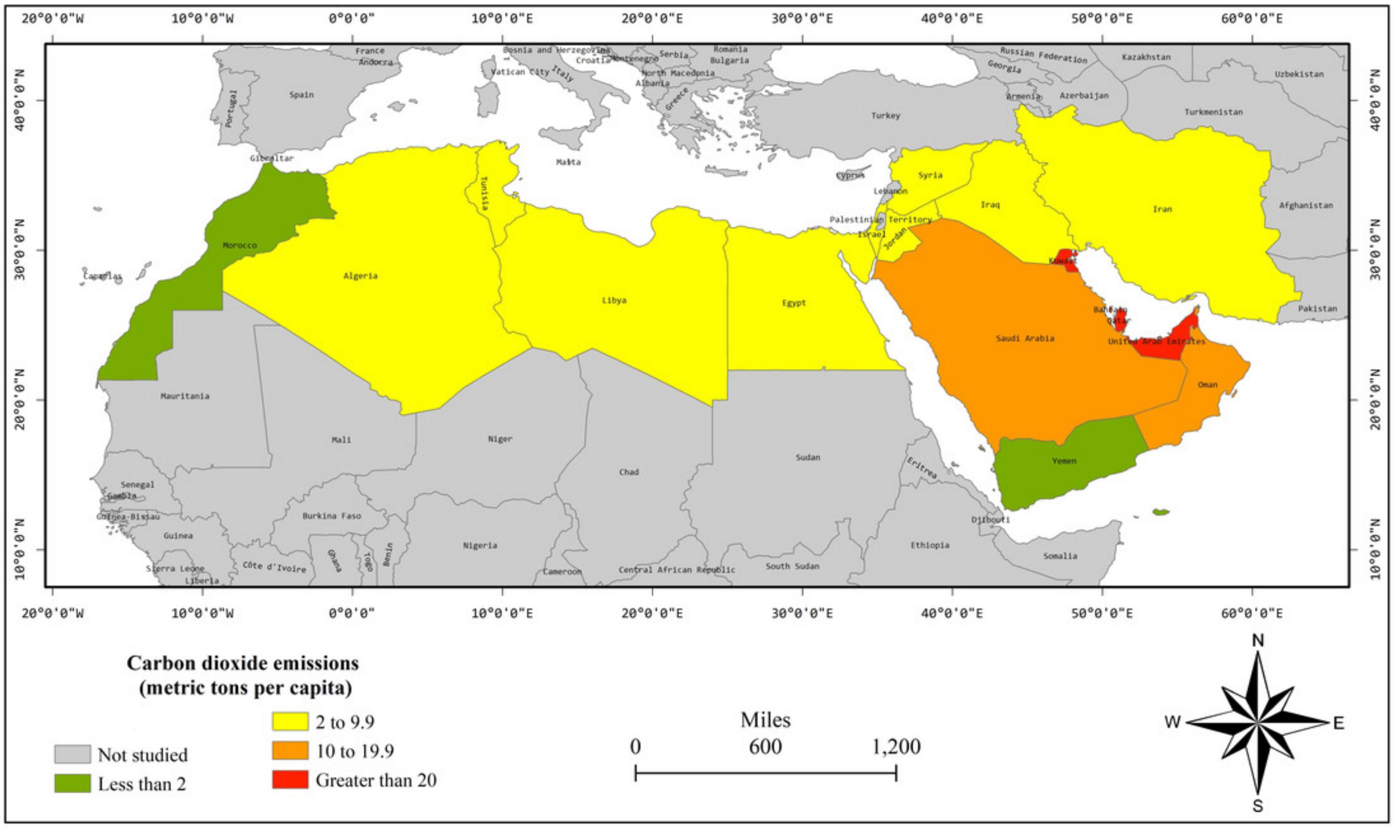

Table 1(on next page)

Non-spatial results

Table 1 Non-spatial results.

Variable	Pooled regression	FE-country	FE-time	FE-both
Y_{it}	1.1423 (0.001)	3.5157 (0.000)	1.1851 (0.001)	3.7262 (0.000)
Y_{it}^2	-0.0184 (0.326)	-0.1565 (0.000)	-0.0211 (0.276)	-0.1662 (0.000)
OR_{it}	0.6809 (0.000)	0.0683 (0.405)	0.7210 (0.000)	-0.2261 (0.046)
NGR_{it}	9.2220 (0.000)	-0.0945 (0.911)	10.2027 (0.000)	0.1356 (0.899)
LM Spatial Lag	776.224 0.000)	441.045 (0.000)	798.788 (0.000)	419.290 (0.000)
Robust LM Spatial Lag	15.366 (0.000)	63.744 (0.000)	10.972 (0.001)	57.044 (0.000)
LM Spatial Error	814.217(0.000)	399.113 (0.000)	837.734 (0.000)	396.435 (0.000)
Robust LM Spatial Error	53.360 (0.000)	21.811 (0.000)	49.918 (0.000)	34.189 (0.000)
σ^2	0.1395	0.0115	0.1447	0.0110
R^2	0.8892	0.9912	0.8915	0.9925
LR test		864.68 (0.000)	7.29 (0.992)	900.81 (0.000)

Note: Probability values are presented in ().

Table 2(on next page)

SDM results

Table 2: SDM results.

	FE with both Parameter (p-value)	RE with both Parameter (p-value)
Point Estimates		
Y_{it}	3.4945 (0.000)	3.5058 (0.000)
Y_{it}^2	-0.1533 (0.000)	-0.1559 (0.000)
OR_{it}	-0.2040 (0.041)	-0.2274 (0.063)
NGR_{it}	1.0425 (0.270)	-0.4372 (0.693)
Direct Estimates		
Y_{it}	3.5486 (0.000)	3.5784 (0.000)
Y_{it}^2	-0.1557 (0.000)	-0.1589 (0.000)
OR_{it}	-0.2117 (0.032)	-0.2492 (0.021)
NGR_{it}	1.0022 (0.290)	-0.0940 (0.929)
Indirect Estimates		
Y_{it}	-1.1718 (0.000)	-1.4848 (0.000)
Y_{it}^2	0.0432 (0.007)	0.0476 (0.015)
OR_{it}	0.5328 (0.000)	0.9406 (0.228)
NGR_{it}	0.8547 (0.559)	-9.1355 (0.150)
Total Estimates		
Y_{it}	2.3768 (0.000)	2.0936 (0.000)
Y_{it}^2	-0.1125 (0.000)	-0.1113 (0.000)
OR_{it}	0.3211 (0.001)	0.6914 (0.394)
NGR_{it}	1.8569 (0.186)	-9.2295 (0.165)
Weights		
$W*Y_{it}$	-0.2364 (0.171)	-0.5226 (0.283)
$W*OR_{it}$	0.6457 (0.000)	1.1018 (0.310)
$W*NGR_{it}$	1.6272 (0.370)	-12.4940 (0.131)
$W*CO2_{it}$	0.3944 (0.024)	0.4337 (0.039)
R^2	0.8660	0.8583
σ^2	0.0102 (0.000)	0.0090 (0.000)
Spatial Lag-LR Test	21.18 (0.000)	28.36 (0.000)
Spatial Error-LR Test	35.38 (0.000)	39.58 (0.000)
Spatial Lag-Wald Test	21.89 (0.000)	24.42 (0.00)
Spatial Error-Wald Test	19.60 (0.000)	11.66 (0.009)
Hausman Test	83.18 (0.000)	