Renewable energies and energy efficiency adoption's impact on the environmental quality of MENA countries

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Abstract: Environmental challenges in MENA countries deserve more attention as they are pursuing economic growth and expanding urbanization, and the geographical position of these countries make them more exposed to the outcomes of climate change. In this context, this paper focuses on the proposed solutions for the climate change problem that are renewable energies and the use of fossil fuel effectively in the context of growing urbanization in the MENA region. Indeed, using the GMM estimator for 18 MENA countries during the period 2000-2018, we try to quantify the magnitude of the impact of population, economic prosperity, urbanization, fossil fuels, energy efficiency, and renewable energies, especially solar, wind, and hydropower energies on CO_2 emissions. Results allow the environmental Kuznets curve validation and highlight the contribution of energy efficiency in improving the environment. However, the used proportion of renewables in the energy mix does not significantly affect environmental quality. Moreover, solar energy contributes to emissions reduction. While the adopted level of wind and hydropower energy does not allow these countries to improve their environment.

Keywords: Renewable energy, energy efficiency, Solar energy, Wind energy, Hydropower energy

1. Introduction

Human needs are unlimited and evolutionary. Economic actors are carrying economic activities and are exploiting resources that are scarce to meet their needs. The contradiction between scarce resources and infinite needs entails overexploitation of natural resources and the development of an economic activity that generates positive and negative externalities. Greenhouse gas and CO_2 emissions are among negative externalities that alter environmental quality.

Since the industrial revolution, environmental degradation was caused by intensive energy production systems adoption. Indeed, climate change causes growth of the global mean annual temperatures by 3°C to 5°C by the next century. Wodon et al. (2014) stated that the Middle East and North Africa (MENA) region would be strongly affected by climate change. Environmental degradation differs in terms of severity according to the geographical positions of these countries. Decreased precipitation, Mediterranean ocean level increase, and considerable seasonal temperature variability are among climate change results, Verner (2012).

In addition to water quality and scarcity, land desertification, urban pollution, coastal and marine degradation, and air pollution. This climate variability represents threats to the life security of people, agricultural production, tourism, and economic activity.

Researchers examined the effects of economic development on the environment (Bargaoui et al. 2014; Adedoyin et al. 2020; Munir et al. 2020; Alharthi et al. 2021). Some studies deal with the environmental Kuznets curve (EKC) theory to study the relationship between economic growth and environmental degradation that takes an inverted U-shape meaning that the rise of per capita income is associated with an increase of pollution until achieving a turning point corresponding to the maximum level of pollution from which emissions start to decline (Bargaoui et al., 2013). According to the World Bank MENA economic monitor, economic growth increased to 3% in 2018 and 3.2% in 2019 after implementing reforms to overcome the negative consequences of revolutions, war, violence, and low oil prices lived by some of the MENA countries. The first challenge of MENA countries is how to adopt an eco-friendly economic model to attain sustainable growth?

Moreover, previous studies demonstrated that population growth entails emissions growth for some countries or groups of countries (Bargaoui et al.,2014; Abdallh and Abugamos, 2017; ...). The population division of the United Nations (2013) expected population evolution in MENA countries to pass from 341 million in 2015 to 571 million in 2050 and 685 million in 2070. Then, it will be crucial to measure the impact of the population number on emissions to give decision-makers a dashboard that can guide their decisions. Indeed, the second challenge of MENA countries is to implement strategies aiming to reduce population fertility and to carry out programs to make their citizens socially responsible consumers.

Urbanization was identified as one of the significant factors that can explain the environmental quality. Péridy et al. (2012) stated that an increase in temperature of 1-3 °C could expose around 6–25 million people to coastal flooding in urban areas of MENA countries. Furthermore, the United Nations revision of the World Urbanization Prospects (2018) reported that the total number of urban inhabitants in the region was 188 million in 2000, 281 million in 2015, and is projected to reach 381 million in 2030, and 527 million in 2050. In relative terms, the MENA region's urban population evolution is faster than that of its population. Urban people change their consumption mode notably: food, energy, water, and land; that entails environment quality alteration, which influences their health and life quality. Consequently, the climate risk will affect a growing number of MENA urban citizens. An additional challenge for these countries consists in reducing urban population impact on their environment through socially responsible consumption.

Compared to other regions, MENA possesses the largest natural gas and oil reserves in the world, World Bank (2020). Indeed, according to the BP Statistical Review of World Energy (2018), these countries possess 60% of the global oil reserves. However, the region is heterogeneous in terms of natural resources endowment since its composition of gulf countries that are oil prosperous economies and scare resources countries. Collectively, they are considered the wealthiest in oil and gas dotation and the poorest in water worldwide. Indeed, Menichetti and El Gharras (2017) stated that the MENA countries held 51.2 % of global oil proved reserves in 2015 and 47 % of world gas proved reserves. In terms of consumption, MENA countries need more fossil fuels to pursue their economic growth and expanding urbanization. Empirical investigations agreed that energy consumption and economic growth are the main CO_2 emissions drivers (Arouri et al., 2012; Farhani et al., 2013; Omri, 2013; Bargaoui et al., 2014; Abdallh and Abugamos, 2017). Since the region is attempting to modernize its economies and is engaging in an industrialization process, MENA countries are facing carbon emissions growth.

Institutional awareness was known by the international community beginning with the United Nations Framework Convention on Climate Change (UNFCCC) negotiated and signed by 154 states at the United Nations Conference on Environment and Development (UNCED) in 1992. After this date, several conferences of parties were organized among them the Kyoto protocol in 1997, the Paris agreement in 2015, and the United Nations Conference of 2017. These succussed events led to the elaboration of the United Nations agenda of Sustainable Development Goals 2030 that contains 17 goals among them: Affordable and clean energy, Responsible consumption and production, and climate action. States tried to develop a certain number of policies and practices to attain these goals. In this sense, Kaygusuz et al. (2007) emphasized that renewable energy allows coping with resources scarcity and limits its incidence on our environment. Likewise, the convention signed at United Nations Climate Change Conference organized in December 2015 in Paris acknowledged that energy efficiency is a serious instrument to face climate change. The Paris agreement, which deals with Greenhouse Gas emissions mitigation, adaptation, and sustainable projects financing became into force in 2020, was ratified by all MENA countries except Iran, Iraq, Libya, and Yemen. In this sense, environmental institutions, legal framework development, investment in projects to manage waste, development of strategies to mitigate climate change and to manage scarce resources, and research and development effort deployment to invent new technologies that exploit scarce resources effectively and develop new energies that are renewable and eco-friendly are among challenges of MENA countries. This region possesses the most important renewable energy dotation in the world. Little countries of this region began to exploit their potential of renewable energies, particularly scarce resource countries, as fossil fuels still dominate the energy mix.

Renewable energies are generated from numerous sources involving biomass, geothermal, solar, wind, and hydropower energies. Since the composition of MENA countries of net energy importers and net energy exporters, there is a difference in renewable energy adoption. Indeed, for energy-exporting countries, the energy mix is depending on fossil fuels, and renewable energy sources are weakly adopted. Contrary, energy importers tried to be seriously involved in the energy transition process toward renewables. The last challenge of the MENA countries is to develop renewables. According to Menichetti and El Gharras (2017), the most dominant source is hydropower, wind, and solar energy is experiencing a significant development achieving more than 21 Mtoe in 2014 in South and East Mediterranean countries. Indeed, they stated that except hydropower, renewable energy installed capacity in the MENA region is around 11GW and is distributed: wind (7.5 GW), solar photovoltaic (1.7 GW), geothermal (775 MW), biomass and waste (650 MW), and concentrated solar power (347 MW). Some researchers tried to investigate the impact of some renewable energies on environmental quality for some countries or groups of countries. However, to the best of our knowledge, their respective roles for MENA countries are not well investigated yet.

Since environmental challenges deserve particular attention, this chapter aims to quantify the magnitude of the impact of the proposed solutions for the climate change problem that are renewable energies and the use of fossil fuel effectively in the context of growing urbanization in the MENA region. Indeed, using the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model estimated by the generalized method of moments (GMM) for 18 MENA countries during the period 2000-2018, we try to quantify the magnitude of the impact of population, economic prosperity, urbanization, fossil fuels, energy efficiency, and renewable energies, especially solar, wind and hydropower energies on CO_2 emissions. To this end, five models were estimated to validate our hypothesis.

The rest of the chapter is organized as follows: Section 2 presents a literature revue of the implications of economic growth, energy consumption, population, and urbanization on environmental quality. Section 3 provides MENA countries environmental challenges. Section 4 allows the quantification of the magnitude of the implication of economic growth, population, urbanization as well as energy efficiency and adopted renewable energies in MENA countries on environmental quality. Section 5 concludes and presents policy implications.

2. Economic growth, energy consumption, population, and urbanization implications on environmental quality

During past decades, the linkages between economic growth, energy consumption, population, urbanization, and environmental quality interested considerable academic researchers. Subsequently to the international awareness about climate change, the imperative to improve human well-being via the effective use of available resources and the continued prosperity of their economies. MENA countries are among these nations that aim to attain sustainable development and create green economies. Indeed, Jalilvand (2012) stated that greenhouse gas emissions from energy consumption are expected to grow globally in 2035 compared to 2010 by 20%. He added that the growth is more valuable in the Middle East for which the increase is by 47%. Then, it is obvious to study the linkages between energy consumption, economic growth, and CO_2 emissions as these later are the most significant greenhouse gas emissions.

In this context, Arouri et al. (2012) used the panel error-correction model to study the impact of energy consumption and real GDP on CO_2 emissions for 12 MENA Countries over 1981–2005. They demonstrated that a 1% increase in energy consumption per capita increases CO_2 emissions per capita by 0.47% in the MENA region, and gross domestic product growth causes future decreases in carbon dioxide emissions per capita. Consequently, they validated the EKC hypothesis.

Using the Cobb–Douglas production function, Omri (2013) examined the above interaction for 14 MENA countries during 1990-2011 and found that energy consumption contributes to economic growth and rejected the neoclassical assumption of neutrality of the energy/growth nexus. Besides, the researcher demonstrated a unidirectional causal relationship between energy consumption to carbon dioxide emissions. Consequently, they concluded that the

MENA countries are consuming more energy because of the expansion of production, which leads to more emissions.

Bargaoui et al. (2014) examined the relationship between economic growth, population and CO_2 emission level during 1980-2010 using static and dynamic panel data estimations for 151 countries studied collectively and decomposed in geographical groups. Results of static model estimation reveal that population and growth exhibit a positive and statistically significant for all the studied countries sample and different geographic groups of countries. However, economic growth loses its significativity for the dynamic panel for East Asia and Pacific, Europe and Central Asia, Latin America and Caribbean, and MENA groups.

Alharthi et al. (2021) investigated the contributing factors of CO_2 emissions in the MENA region by applying novel quantile techniques during 1990-2015. Empirical results confirm the validity of the EKC hypothesis. Furthermore, non-renewable energy consumption grows CO_2 emissions, and its magnitude decreases with higher quantiles.

The negative impact of climate change on agriculture is probably to have additional negative consequences on rural-urban migration via an increased urbanization process that includes negatives outcomes, such as housing, job opportunities, and investments in infrastructure, Péridy et al. (2012). In this context, Cole and Neumayer (2004) studied a panel of 86 countries during 1975-1998 and found a positive association between CO_2 emissions and population, urbanization rate, energy intensity.

Using the dynamic ordinary least squares (OLS) technique for 20 MENA countries during 1980–2009, AlMulali et al. (2013) demonstrated that higher urbanization and energy usage leads to further environmental degradation.

Using static panel data estimation, Bargaoui et al. (2014) demonstrated that urbanization exerts a negative and significant effect on emissions for all countries sample, East Asia and Pacific, Europe and Central Asia, and South Asia groups. Yet, this relation is statistically positive in Latin America and the Caribbean, Sub-Saharan Africa, and MENA groups. For For dynamic panel data, all linkages lose their significance except for the Sub-Saharan Africa group. Urbanization does not exert a statistically significant effect on emissions except for Sub-Saharan Africa for which urbanization enhances emissions.

Solarin et al. (2017) studied the relationship between CO_2 emissions, urbanization, and real GDP in China and India during 1965–2013 using the ARDL. They showed that real GDP and urbanization have a long-run positive impact on emissions.

Abdallh and Abugamos (2017) explored the impact of urbanization on CO_2 emissions for 20 MENA countries during 1980–2014. They proved that GDP per capita, total population, and energy intensity add significantly to the CO_2 emissions level and that urbanization has not a statistically significant impact on emissions.

Bello et al. (2018) studied the relationship between CO_2 emission, GDP, squared GDP, and urbanization for the period going from 1971 to 2016 for the Malaysian economy. Their results proved an inverted U-shaped relationship between environmental degradation and real GDP, confirming the EKC hypothesis. The authors demonstrated that urbanization is not particularly harmful to the environment.

Magazzino and Cerulli (2019) conducted a study on 18 MENA countries for the period 1971-2013 to explore the association between carbon emissions and urban population using the responsiveness scores. Their results reveal that the urban population influence CO_2 negatively.

Using the Augmented Mean Group algorithm, Nathaniel et al. (2020) tried to determine the effect of financial development, economic growth, non-renewable energy consumption, and urbanization on environmental quality as measured by ecological footprint for 13 MENA countries during 1990-2016. Their finding suggested that financial development, economic growth, non-renewable energy consumption, and urbanization enhance environmental degradation. Results for the emissions urbanization relationship are controversy. This fact inspires as to study this linkage in the present work.

3. MENA countries environmental challenges

As explained in the previous section via prior empirical research developments, there is a bidirectional relationship between CO_2 emissions and economic growth. Meaning that economic growth entails negative externalities that may affect the well-being of citizens if it continues in time. Indeed, threats alter the health of actual generations by waste and discharges. However, future generations may experience a non-renewable energy shortage since their overexploitation by present ones. Consequently, decreased productivity and life quality can occur. In this context, the pollution control actions application via the R&D and investment in energy effective equipment and the energy mix modification through the renewable energy adoption become crucial. Indeed, attempts must be made to persuade industrials to implement new technologies to minimize pollution. In this framework, Péridy et al. (2012) stated that adaptation measures in MENA countries should focus on low-cost adaptation measures based on traditional knowledge, meeting domestic and local conditions. Indeed, considering the negative climate change impact experienced by each nation and its affected sectors, each country set a priority list in addition to general policies that are adaptable to most MENA countries.

The effectiveness of energy efficiency has been the subject of some empirical studies. Indeed, Martínez-Zarzoso (2009) studied the energy efficiency/CO_2 emissions nexus for a sample of 121 countries over the period 1975-2003 and proved that adopting energy-efficient technologies reduces emissions and that the magnitude of impact is more important for high income than low-income countries.

Using static and dynamic panel data, Bargaoui et al. (2014) demonstrated, for all studied samples and groups, that energy efficiency reduced CO_2 emissions. However, the magnitude of impact differs among studied groups. Indeed, the impact magnitude for 20 MENA countries is -0.5291 against -0.8299 for the studied sample composed of 151 countries. These results can be attributed to the weak energy-efficient technologies' level in MENA countries and even the studied period stemming from 1980 to 2010, a period known by the lack of energy-efficient technologies since they are under development. Then, the studied period 2000-2018 in the present work will allow for better estimating MENA countries' energy-efficient technologies adoption outcomes.

Although there is a theoretical consensual opinion about the role of renewable energy in environmental quality improvement, controversial results proved by several empirical research regards the renewable energy and CO_2 emissions relationship. Indeed, while some researchers confirmed that renewables decrease emissions as Mert and Bölük (2016), Heryadi and Hartono (2016), Mbarek et al. (2016), Dogan and Ozturk (2017), Paramati et al. (2017), Charfeddine and Kahia (2019), Majeed and Luni (2019), and Bargaoui and Amamou (2020); others proved the opposite relation such as Apergis et al. (2010), and Jebli and Youssef (2017).

By employing the PVAR technique, Charfeddine and Kahia (2019) examined the impact of renewable energy consumption on CO_2 emissions in the MENA region. Results indicated the possibility of improving the environmental quality in the MENA region by promoting the renewable energy sector since they proved the statistically significant negative link between renewable energy consumption and CO_2 emissions.

Anser et al. (2020) assessed the influence of non-renewable, renewable energy consumption, and economic development on emissions in Latin America and the Caribbean during 1990-2015 using the system GMM estimator. They showed that economic growth, annual per capita fossil fuel consumption, and urbanization significantly increase CO_2 emissions. In contrast, the squared GDP and renewable energy consumption significantly improve the environmental quality through CO_2 emissions reduction.

Nathaniel et al. (2020) explored the impact of renewable energy on environmental quality for 13 MENA countries on ecological footprint and proved that renewable energy does not contribute significantly to environmental quality.

Recently, the renewable energy CO_2 emissions were studied by Alharthi et al. (2021) for 15 MENA countries during 1990-2015 and showed that renewable energy consumption significantly reduces the level of emissions and that its impact increases with higher quantiles.

Heryadi and Hartono (2016) tried to study the effectiveness of the joint implementation of energy efficiency and renewable energy for G20 countries during 2000-2013. They proved that energy efficiency and renewable energy negatively affect CO_2 emissions levels, individually and collectively. Besides, they demonstrated that renewable energy adoption has a superior effect than energy efficiency reducing CO_2 emissions.

Renewable energy production is performed from numerous sources that are hydropower, solar, wind, biomass, and geothermal energy. However, their degree of adoption depends on countries' action plans and their dotation in these specific resources. According to our appreciation, these are the cause of these contradictory results since they studied different countries or groups of countries and diverse periods. Then, we believe that exploring the individual impact of each renewable resource on emissions is crucial to detect the magnitude of their mitigation effect and then evaluate the effectiveness of implemented plans.

A limited number of studies are interested in the impact of each renewable resource on environmental quality. Tugcu et al. (2012), Gomiero (2015), Xu et al. (2020), and Busu and Nedelco (2021) examined the influence of biofuel. Their findings support that biofuel and CO_2 emissions reduction are strongly correlated. As for the impact of biomass, the reduced share of biomass in the energy consumption mix contributed significantly to enhance carbon emissions in the Chinese context, Ma and Stern (2008). However, Shahbaz (2018) showed that biomass energy consumption provides CO_2 emissions increase for G7 countries. However, Ahmed et al. (2016) demonstrated that biomass energy is related to CO_2 emissions insignificantly for 24 European countries throughout the period stemming from 1980 to 2010.

Shahbaz et al. (2019) demonstrated that persisting economic growth pattern in the MENA countries is not eco-friendly and is harmful to sustainable development in these nations when analyzing the association between GDP, biomass energy consumption, and CO_2 emissions during 1990-2015. Indeed, results showed an N-shaped association between GDP and CO_2 emissions, whereas biomass energy consumption decreased CO_2 emissions.

The environmental impact of wind energy adoption was studied by Biresselioglu et al. (2016) during 1997-2014 for 26 countries that proved that higher carbon dioxide emissions contribute to developing installed wind capacity. The impact of wind energy on carbon emissions was not analyzed yet by prior researchers.

Lau et al. (2016) used the standard time series estimation to determine the long-run relationship between hydroelectricity consumption and CO_2 emissions in Malaysia. Their results confirm the short and long-run causality from hydroelectricity consumption to CO_2 emissions.

Solarin et al. (2017) examined the link between CO_2 emissions and hydroelectricity consumption in China and India from 1965 to 2013. They showed that hydroelectricity consumption exerts a long-run negative impact on emission in both countries. Besides, Bello et al. (2018) explored the isolated impact of hydroelectricity consumption on the environment in Malaysia. They found that hydroelectricity reduces environmental degradation significantly.

Al-Mulali et al. (2015) studied the renewable electricity production by source on CO_2 emissions in 23 selected European countries for the period of 1990–2013. Their renewable electricity generated from combustible renewables and waste, hydroelectricity, and nuclear power have a negative long-run effect on CO_2 emissions, while renewable electricity generated from solar power and wind power is insignificant.

Furthermore, Majeed and Luni (2019) investigated the role of renewable energy and hydroelectricity solely in addition to that of solar, wind, geothermal, and hydroelectricity considered collectively on carbon dioxide emissions for 166 countries during 1990-2017. Empirical results indicated the positive role of solar, wind, geothermal, and hydroelectricity in environmental improvement.

In the path of the literature review, we have not arisen across any study that carried out on the MENA countries focusing on the effect of renewable energy and energy efficiency adoption collectively, and studies regarding renewable energy produced dissociated results. Furthermore, the study of the influence of each renewable energy solely on emissions for MENA countries is not considered by previous studies to our knowledge. Focusing on these gaps represents the main contributions of this book chapter. In addition, policy prescriptions for MENA countries considering presented results to allow these nations to attain sustainable development goals developed by the United Nations.

4. **What is the magnitude of the implication of economic growth, population, and urbanization on emissions? and Does energy efficiency, adopted renewable energy in MENA improves environmental quality?**

It is essential to quantify the magnitude of the impact of the anthropogenic factors that entail emissions growth and adopted policies to mitigate this effect. Hence, we apply the STIRPAT model (Stochastic Impact by Regression on Population, Affluence, and Technology) that allows studying the multiple factors contributors to environmental degradation such as urbanization, population, and economic growth. The STIRPAT model was advanced by Dietz and Rosa (1997) to surmount the IPAT model problems. The STIRPAT equation is as follow:

$$\boldsymbol{I_i = \alpha . P_i^{\beta} . A_i^{\gamma} . T_i^{\delta} . e_i} \quad \textbf{(1)}$$

To interpret explanatory variables as elasticity, we apply a logarithmic transformation to equation (1) as recommended by York et al. (2003):

$$\boldsymbol{lnI_{it} = \alpha_i + \beta lnP_{it} + \gamma lnA_{it} + \delta lnT_{it} + \mu_i + \theta_t + e_{it}} \quad \textbf{(2)}$$

Where i represents countries, t studied years, I_{it}: CO_2 emissions of the 18 MENA countries; P_{it}: Total population; A_{it}: GDP per capita. T_{it}: approximated by GDP per unit of energy use that represents energy efficiency, fossil fuel consumption, and renewable energies that are solar, wind, and hydropower energy. μ_i: countries fixed effect and θ_t: time effect and e_{it}: error term. To test the relationship between urbanization and environmental impact, we use the percentage of the urban population as York et al. (2010).

The expected models allow us to test the following hypothesis:

H_1: There is a positive link between CO_2 emissions and population in MENA countries.

H_2: There is a positive link between CO_2 emissions and GDP in MENA countries.

H_3: There is a negative link between CO_2 emissions and GDP^2 in MENA countries.

H_4: There is a positive link between CO_2 emissions and urbanization in MENA countries.

H_5: There is a positive link between CO_2 emissions and fossil fuel energy in MENA countries.

H_6: There is a negative link between CO_2 emissions and energy efficiency in MENA countries.

H_7: There is a negative link between CO_2 emissions and renewable energy in MENA countries.

H_8: There is a negative link between CO_2 emissions and wind energy in MENA countries.

H_9: There is a negative link between CO_2 emissions and solar energy in MENA countries.

H_{10}: There is a negative link between CO_2 emissions and Hydropower energy in MENA countries.

To estimate our model, we use the General Method of Moments (GMM) approach; and to test the validity of instruments, we apply the Sargan and Arellano-Bond statistical test.

We use annual data for the 18 MENA countries that are Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, the United Arab Emirates, and Yemen for the period spanning from 2000 to 2018. The first group of data is sourced from World Development Indicators (WDI) that are: CO_2

emissions (in KT) to measure environmental impact; population quantified by the total number of populations; urbanization is proxied by the percentage of the population living in urban areas; affluence assessed by GDP per capita (constant 2010 US$); fossil fuels proxied by the percentage of fossil fuel energy consumption that comprises coal, oil, petroleum, and natural gas product; energy efficiency measured by GDP per unit of energy use is the PPP GDP per kilogram of oil equivalent of energy use; and the percentage of renewable energy consumption from final energy consumption. To further analyze the impact of renewables, we proxied renewables by electricity generated from hydropower in TWh, electricity generated from solar energy in TWh, and electricity generated from wind energy in TWh. These three proxies' source is Our World in Data. The descriptive statistics of used variables are presented in the table2 (See appendix) are crucial to conducting our study.

Insert table 2

As for the minimum and maximum values are discarded. CO_2 emissions and GDP are volatile. The correlations between the studied variables are presented in Table 3.

Insert table 3

All studied variables are highly correlated with CO_2 emissions except urbanization, solar, and wind energy that show a weak correlation. The next step consists of the models' estimation. These allow us to measure the elasticity of the different driving forces of CO_2 emissions and solutions that are energy efficiency, renewable energies, and more precisely solar, wind, and hydropower energy. Consequently, policymakers can use these results to evaluate adopted solutions' implications on environmental quality. Estimation results are presented in Table 4.

Insert table 4

The first step is to test the validity of our estimates through the Sargan test that allows us to examine the validity of the instruments and the Arellano-Bond statistical test to analyze the autocorrelation of the first-order and second-order errors. As for the Sargan test, if the p-value is superior to 5%, we accept the null hypothesis according to which the p-instruments are valid. Consequently, instrumental variables are not asymptotically correlated with the perturbations of the estimated model. The p-values of all estimated models are superior to 5%. Then we accept the null hypothesis of the absence of autocorrelation. This result does not disturb the consistency of our findings because it measures the autocorrelation in difference. Several researchers consider that the second-order error autocorrelation test AR (2) is more essential because it permits perception-level autocorrelations. The p-values of this statistic are all greater than 5% showing the absence of second-order autocorrelation for all estimated models.

After testing the validity of our estimated model, we can interpret our results. The first model aims to verify the Kuznets hypothesis that is validated for MENA countries according to our estimation results are in line with those found by Arouri et al. (2012) and Elharthi et al. (2021). Population level has a positive effect, and urbanization has not statistically significant impact on environmental quality. Energy efficiency contributes to the improvement of the environment.

The second model concerns the role of renewable energy adoption in pollution mitigation. Results suggest that renewable has not a statistically significant impact and energy efficiency decreases CO_2 emissions. Population, economic growth, and fossil fuels deteriorate environmental quality. As for population level, GDP, and CO_2 emissions relationship, our results are consistent with those of Bargaoui et al. (2014), Abdallh and Abugamos (2017), and that of fossil fuel impact agrees with those of Arouri et al. (2012), and Omri (2013), which proved that energy consumption enhances CO_2 emissions for respectively 12 and 14 MENA countries.

Since renewable energy have not statistically significant effect, and it is composed of several types, we find it crucial to measure the implication of each type solely to have an idea about the most effective adopted strategy. For this, we estimate the impact of wind, solar, and hydropower energy. The result of the third model indicates that wind energy does not significantly affect emissions levels. The outcomes of the only research examining this relationship for 23 selected European countries that is AlMulali (2015) are in line with our findings. As for population, economic prosperity, and fossil fuels, they contribute to environmental quality deterioration.

The solar energy effect examined in the fourth model significantly reduces emissions. Indeed, a 1% increase in solar energy entails a decrease of -0.01442% in emissions level. However, this renewable has not significant effect on 23 European countries studied by AlMulali (2015). Besides, energy efficiency seems to have a considerable impact on environmental quality. A 1% increase in energy efficiency leads to a decrease in emissions level of -0.924%. These outcomes are consistent with those of Martinez-Zarzoso (2009) and Bargaoui et al. (2014).

Although hydropower energy is the most adopted renewable energy in the MENA region, we find that hydropower has not statistically significant impact on emissions, as examined by model five. This finding is in discordance with previous studies. Indeed, hydroelectricity is found to reduce emissions by Solarin et al. (2017) for China and India, by Bello et al. (2018) for Malaysia, and by AlMulali (2015) for 23 European countries.

5. Conclusion and policy implications

The collaboration with the international community allows the achievement of sustainable development goals developed by the United Nations programs. MENA countries contemplate a crucial environmental challenge since they are among the most affected nations by climate change. This chapter focused on renewable energies and fossil fuel effective use outcomes in the context of increased urbanization in the MENA region. Indeed, using Generalized Method of Moments (GMM) for 18 MENA countries during the period 2000-2018, we tried to quantify the magnitude of the impact of population, economic prosperity, urbanization, fossil fuels, energy efficiency, and renewable energies, especially solar, wind and hydropower energies on CO_2 emissions. Results confirm the EKC hypothesis for MENA countries. Population exerts pressure on the environment. However, urbanization does not significantly affect emissions for almost all estimated models.

Considering our research results, we conclude that energy efficiency technologies are well adopted in these countries, and their effect magnitude is considerable. Then, we propose new energy-efficient technology supplementary adoption to maintain its positive externality. Results suggest that renewable energy technologies have not significantly reduced the effect on emissions. These can be explained by the fact that they are not yet widely adopted by MENA countries. The only technology that contributes to environmental quality improvement is solar energy, since the dotation of our sample with this natural resource and the installation of the required equipment to exploit them at the required level. Indeed, most MENA countries are sunny. Indeed, according to Menichetti and ElGharras (2017), global horizontal irradiance values range from 1,600 kWh/m²/y in coastal areas of the Mediterranean to 2,600 kWh/m²/y in the desert, and direct normal irradiance varies from 1,800 kWh/m²/y to more than 2,800 kWh/m²/y. Besides, Al-Shalabi et al. (2014) stated that the MENA region is one of the best areas of solar energy i.e. Concentrated Solar Power and Photovoltaic.

As for hydropower and wind energy and even though MENA countries are dotted with these resources, these renewables exhibit a non-significant effect on environmental quality. In this sense, Menichetti et al. (2019) affirmed that hydropower still the main renewable energy in the MENA region, reaching 9 Mtoe in 2015. Besides, Mediterranean MENA countries: Morocco, Egypt and Turkey, and Iran are highly endowed with wind potential, while GCC countries wind energy is relatively moderate. Consequently, MENA countries must focus in installing further equipment to take advantage from their capacities.

To conclude, the MENA region is appropriate for the development of renewable energy technologies. Efforts of MENA countries remain insufficient to induce significant change. Consequently, new governmental policies and structural changes need to be undertaken to achieve the required results. Indeed, nations must establish ambitious objectives and plans to improve and develop renewable energy usage. Especially wind and solar energy, which is existent in these countries and not well exploited yet. At the global level, general policies must be undertaken by most MENA countries in addition to specific policies according to each country's priority and climate change-specific incidences. The challenges of MENA countries consist in removing barriers. Among them: regulatory barriers, weak infrastructure, equipment investment, high level of subvention of conventional energy.

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Appendix

Table1. Variable description

Indicator	Definition	Source
CO_2 emissions (kt)	Carbon dioxide emissions come from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during the consumption of solid, liquid and gaseous fuels and gas flaring.	World development Indicators
Total population	The total population is based on the definition of population, which includes all residents regardless of legal status or citizenship.	World development Indicators
Economic growth GDP per capita, PPP (2011 constant international dollars)	GDP per capita based on Purchasing Power Parity (PPP)	World development Indicators
Fossil fuels: Fossil energy consumption (% of total final energy)	Fossil fuels include coal, oil, petroleum and natural gas products.	World development Indicators
Renewable energy: Renewable energy consumption (% of total final energy consumption)	Renewable energy consumption is the share of renewable energy in total final energy consumption.	World development Indicators
Energy efficiency: GDP per unit of energy use (constant 2011 PPI per kg of oil equivalent)	The GDP per unit of energy use is the PPP GDP per kilogram of oil equivalent of energy consumption.	World development Indicators
Urbanization: Urban population (% of total population)	Urban population refers to people living in urban areas as defined by national statistical offices. The data are collected and smoothed by United Nations Population Division.	World development Indicators
Hydropower	Electricity from Hydro (TWH)	Our World in Data
Wind energy	Wind energy generation is measured in terawatt-hours (TWh)	Our World in Data
Solar energy	Solar energy generation is measured in terawatt-hours (TWh).	Our World in Data

Table 2. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max	Max
LCO_2	324	7.197039	3.483047	2.621039	13.38027	13.38027
LPOP	342	16.0642	1.38231	13.29205	18.40479	18.40479
LGDP	311	17.89678	8.021088	6.450327	27.94583	27.94583
LFF	234	4.572603	0.0464876	4.400486	4.60517	4.60517
LEE	239	2.120601	0.3010105	1.258019	2.659041	2.659041
LRE	224	0.4089528	2.14263	-5.119913	3.53934	3.53934
LURB	342	4.252336	0.2893652	3.268313	4.60517	4.60517
LUHYDRO	171	-0.095572	2.025624	-4.074542	2.906682	2.906682
LSOLAR	150	-5.045889	2.868346	-9.903487	0.2965753	0.2965753
LWIND	128	-2.942939	2.470402	-7.600903	1.321855	1.321855

Table 3. Correlation matrix

	LCO_2	LPOP	LGDP	LEE	LFF	LRE	LURB	LWIND	LSOLAR	LHYDRO
LCO_2	1.0000									
LPOP	0.8558	1.0000								
LGDP	0.9785	0.8670	1.0000							
LEE	-0.7580	-0.4140	-0.6307	1.0000						
LFF	0.9128	0.7876	0.9319	-0.6154	1.0000					
LRE	-0.9226	-0.6047	-0.8800	0.8776	-0.8496	1.0000				
LURB	0.0306	-0.4427	-0.0482	-0.4888	-0.1151	-0.3680	1.0000			
LWIND	0.0288	0.2779	0.1862	0.4940	0.1379	0.1706	-0.4902	1.0000		
LSOLAR	0.0644	0.0891	0.2092	0.2875	0.3180	0.0026	-0.3597	0.5001	1.0000	
LHYDRO	0.8244	0.9812	0.8277	-0.4029	0.7399	-0.5670	-0.4319	0.2552	0.0002	1.0000

Table 4. GMM estimation results

	Model 1	Model 2	Model 3	Model 4	Model 5
$LCO_{2(t-1)}$	0.444282 (2.66)***	-0.0128225 (-0.05)	0.7764269 (6.38)***	-0.045418 (-0.38)	-0.8099974 (-1.19)
LPOP	0.5651926 (2.08)**	1.327943 (1.88)*	0.4997887 (2.55)**	0.2619548 (0.37)	19.11493 (0.93)
LGDP	1.137025 (14.84)***	0.9660521 (1.74)*	0.3206008 (4.52)***	0.8713517 (20.58)***	4.09005 (1.08)
$LGDP^2$	-0.016234 (-5.44)***				
LURB	0.5932464 (0.17)	-3.046069 (-0.96)	-1.909655 (-3.80)***	3.175415 (1.08)	-1.48768 (-0.89)
LEE	-0.573071 (-9.85)***	-0.8835659 (-1.82)*	-0.6737263 (-5.72)***	-0.9240125 (-9.86)***	-2.749411 (-1.50)
LFF	-0.7128726 (-0.45)	2.79287 (-2.49)**	0.725644 (-1.93)*	-0.4137506 (-0.46)	-2.554138 (-0.30)
LRE		0.075185 (0.51)			
LSOLAR				-0.0144267 (-2.60)**	
LWIND			0.0121207 (0.81)		
LHYDRO					0.2877804 (0.95)
Constant	-19.20796 (-1.35)	-9.623946 (-1.40)	-2.660777 (-1.01)	-23.12788 (-5.50)***	-20.93225 (-0.50)
Observations	179	152	38	63	104
Countries	15	12	7	13	8
Instruments nber	20	32	32	32	32
Sargan test	8.679053 (0.7301)	3.75175 (1.0000)	24.91122 (0.4106)	5.939597 (0.9999)	6.25e-12 (1.0000)
Arellano-Bond test AR(1)	-1.9076 (0.0564)	-0.05067 (0.9596)	1.0404 (0.2981)	-0.67058 (0.5025)	0.74433 (0.4567)
Arellano-Bond test AR(2)	-0.2416 (0.8091)	1.4834 (0.1380)	1.2321 (0.2179)	0.9091 (0.3633)	0.70859 (0.4786)

All variables are in natural logarithms. *t*-statistics are given in parenthesis and ***p value < 0.01; **p value < 0.05; *p value < 0.1