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Article

The consumption of renewable energy as a clean and sustainable alternative and its impact on economic growth in the MENA region

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Abstract: Energy, a fundamental pillar of the global economy, plays a vital role for all countries. Its crucial importance in development and its links with multiple aspects of sustainable development are widely recognized. However, the predominance of fossil fuels has led to environmental pressures, adversely impacting society, the economy, and the ecosystem. Transitioning to environmentally friendly renewable energy sources is not just a choice but an imperative to mitigate pollution and reduce dependence on traditional energies. Our study, which offers a unique and novel perspective on the impact of renewable energy consumption on economic growth in the Middle East and North Africa (MENA) region, proposes that transitioning to renewable energy sources can significantly promote sustainable and inclusive growth. Renewable energy has emerged as a clean, sustainable alternative and a critical global energy supply pillar. Given their economic and environmental importance, advancements in developing and implementing renewable energies are considered vital priorities. Our study, with its practical implications specifically tailored for policymakers, aims to understand the impact of renewable energy consumption, population growth, and exports on economic growth in the MENA region. Using a robust econometric methodology based on the ARDL model, we analyze the relationships between these variables from 1991 to 2020. The data, meticulously collected from the World Bank and pre-processed to avoid missing values, provides empirical evidence on the determinants of economic growth in the MENA region. Our findings suggest that if implemented, our study's proposed policy recommendations can significantly promote sustainable and inclusive growth in the area. This makes our study a crucial resource for those interested in the region's economic and environmental development, particularly policymakers seeking to drive sustainable economic growth.

Keywords: renewable energy consumption; population; exports; economic growth; MENA region; ARDL model

1. Introduction

Undeniably, renewable energy is increasingly crucial in global economic and sustainable development. The presence of these energy sources, which are essential for ensuring energy security, is central to achieving sustainability objectives. Reducing poverty, promoting social justice, stimulating economic growth, and preserving the environment are goals that have become increasingly important globally.

In this context, many governments, including Morocco, a major player in the Middle East and North Africa region, have committed themselves to promoting, improving, and supporting the sustainability of renewable energies. One example is implementing an integrated and sustainable energy strategy in Morocco, which aims to expand its energy sources and improve energy efficiency by 2030. Following the adoption of the National Plan of Priority Action between 2009 and 2013, this initiative marks the beginning of energy efficiency in the country by introducing a National Energy Strategy.

Measures to improve energy efficiency have already been implemented, with considerable energy savings, national capacity-building, and greater awareness-raising. However, Morocco is pursuing its aspirations by further integrating energy efficiency as an essential element of its energy transition. A particular strategic approach has been developed in this context, requiring a wide-ranging and participatory national consultation involving all stakeholders.

The MENA region, with its vast potential for producing renewable energy, particularly wind and solar, presents an extraordinary opportunity. The area can accelerate its economic growth and significantly reduce carbon dioxide (CO_2) emissions by harnessing these resources. The transition to a renewable-energy-oriented energy system necessitates large-scale implementation of these technologies, appropriate infrastructure development, adequate regulatory frameworks, and stimulation of new markets and industries.

Our study's primary objective is to examine how renewable energy consumption, population growth, and exports influence economic growth in the MENA region. Through robust econometric methodology and World Bank data from 1991 to 2020, we aim to provide crucial information to the academic community and enrich economic literature. This study delves into the key factors that shape economic growth in a region of both geographical and economic significance.

1.1. Renewable energy, CO_2, and economic growth

The term "renewable energy" refers to energy generated from natural renewable sources, such as the sun and wind, which are inexhaustible and easily accessible. These sources stand out for their ability to produce energy by emitting far lower emissions than fossil fuels, enabling them to contribute to the fight against climate change. Moreover, renewable energies are famous for their capacity to create a much higher number of jobs than fossil fuels, adopting different technologies such as geothermal, wave energy, hydraulics, and biomass, all appreciated for their low environmental impact.

The adoption of renewable energies, such as solar, wind, hydraulics, biomass, geothermal, and marine energy, has played an essential role in Morocco's national strategy to improve the sustainability of its energy consumption. In 2019, these sources accounted for 9.7% of the country's national energy consumption and 19% of its electricity production, demonstrating Morocco's commitment to sustainability. This concept aims to reconcile development, industrial advances, and environmental conservation and integrate ecological and social concerns into the development process.

Various experiments and studies have demonstrated the symbiotic relationship between economic growth and the environment. The sustainability of the economy depends on the preservation of the environment and the sustainable management of natural resources, thus promoting sustainable economic growth. The sustainability of the economy relies on the conservation of the environment and the sustainable management of natural resources, thus promoting sustainable economic growth. According to the Kuznets environmental curve model, from a certain level of income onwards, the focus is on reducing environmental impact, leading to an improvement in environmental quality as GDP per capita increases.

Global cases, such as those in Japan and China, demonstrate the importance of government policies in the transition to more environmentally friendly economies, highlighting emerging industries such as wind and solar as national strategic players. Similarly, in the MENA region, government aid is essential in promoting sustainable investments, whether in renewable energy or energy efficiency, highlighting the importance of these initiatives for investors' financial stability.

In Morocco, establishing a funding program for the development of renewable energies, with the support of Saudi Arabia, the United Arab Emirates, and the Hassan II Foundation, aims to promote the adoption of solar technologies and reduce the country's energy dependence.

The endogenous growth theory, introduced by Romer (1986) and further developed by Lucas (1988), suggests that internal economic factors influence economic growth. This theory differs from previous models, such as Solow's (1956) model, which attributed growth to external factors like savings rates, capital depreciation, and an increase in the working population. Endogenous growth theory focuses more on the economy's internal competencies to generate sustainable growth without considering pre-established external constraints. This lays the foundations for sustained and autonomous economic development.

Economists believe developing countries must achieve an annual real growth rate of around 7.0% to achieve the 2030 Sustainable Development Goals. In many Arab countries, reaching this rate could significantly reduce challenges like poverty, unemployment, debt, and budget deficits. According to the OECD (2014), modern research on economic growth highlights the importance of human capital through education as a significant contributor to this expansion.

Economists examine the link between energy consumption, CO_2 emissions, and economic growth from different angles. CO_2 emissions, indicators of environmental quality, play a crucial role in this process, as does energy, which is vital for economic and social development (Asghar, 2008; Diallo, 2023; Madaleno and Nogueira, 2023; Zhang et al., 2023).

According to Chen (2017), the Sustainable Development Goals include initiatives to achieve sustainable economic growth, i.e., prosperous development that reduces energy and environmental impacts. This concern is evident in the increasing support for ecological conservation after signing global agreements to decrease emissions. Developed nations, in particular, set an example in terms of significant economic growth, efficient use of energy, and greater environmental awareness.

On the other hand, developing countries often focus on increasing economic growth, sometimes at the expense of the environment, and on increased consumption of energy resources. Pollution is one of the biggest challenges facing countries, requiring measures such as taxing polluters and enacting environmental laws to protect the environment.

Recent studies like Tsimisaraka et al. (2022) show that increased consumption of renewable energy is associated with reduced carbon emissions in the long term and that reduced greenhouse gas emissions can help combat climate change. In the same context, Zhang et al. (2023) emphasize that increased use of non-renewable energy is associated with increased carbon emissions in the long term and that these energy sources negatively impact the environment, including the atmosphere. Furthermore, their study shows a two-way causal relationship between renewable energy consumption and economic growth and that introducing these energy sources does not only have a positive effect on the environment; it implies that economic growth can be exciting and vice versa. Fu et al. (2022) and Madaleno and Nogueira (2023) found that increased use of renewable energy can boost economic growth and increase CO_2 emissions. This comment raises questions about introducing additional policies and measures to reduce the adverse effects of the transition to renewable energies. On the other hand, their study concludes that the consumption of non-renewable energy positively impacts economic growth, thereby raising policymakers' awareness of the energy transition, which requires a balance between economic development and environmental sustainability.

Hence, our first assumption is that increasing renewable energy consumption stimulates economic growth. This assumption is based on the idea that developing and adopting renewable energy sources promote technological innovation, reduce dependence on fossil fuels, and stimulate economic activity in the clean energy sector.

Hypothesis 1: Increased renewable energy adoption correlates with long-term reductions in carbon emissions and significant environmental improvements. At the same time, this transition to renewable energy is likely to stimulate sustainable economic growth.

1.2. Investment and economic growth

It is undeniable that investment, in all its forms, plays a crucial role in stimulating economic growth and increasing capital, regardless of the economic situation. However, the performance of these investments is also strongly influenced by the quality of the environment. A favorable environment encourages economic growth and stability. A favorable environment promotes economic growth and stability. It is crucial to foster this interaction to design an economic growth model that considers social, cultural, and institutional peculiarities while aiming at broad economic and

social objectives. Since the 1990s, the economies of the MENA region have undergone various stages of economic reform characterized by increasing openness to the market economy.

According to the OECD (2021), these reforms were accompanied by a significant increase in GDP, with annual growth rates ranging from 4% to 5.4% from 1995 to 2007.

The study by Nguyen et al. (2018) analyzed Vietnam's economy from 1990 to 2016 and found that public investment positively affects private investment and economic growth in the short and long term. This finding underscores the importance of government measures in supporting economic development by encouraging private investment. Similarly, the study conducted by Marcos and Vale (2022) examined how public investment can promote private investment and economic growth in 21 countries of international monetary cooperation. According to this study, public investment also positively affects the private sector, fostering economic development in both areas.

Furthermore, the research examined the impact of public investment on sustainable economic growth in the European Union and Central Europe emerging countries based on the VAR model from 1995 to 2019. Although the public capital multiplier was mainly positive at the beginning of the period, it turned out to be primarily negative in the medium term, with a few notable exceptions, such as the Czech Republic and Hungary, which displayed a positive multiplicator on both terms. According to research conducted by Ocolișanu and his colleagues (2022), this demonstrates a significant and generally positive effect of public investment in industrialized countries.

Public investment has a significant and beneficial impact in developed countries Ocolișanu et al. (2022).

Hypothesis 2: In an enabling investment environment, investments can promote economic growth and thus contribute to economic progress and stability.

1.3. Population and economic growth

The complexity of the relationship between demography and economics exceeds the simplistic predictions of the Neo-Maltusian theories based on Malthus's ideas. According to Malthus (1798), population growth tends to exceed the capacity to produce the required resources, leading to famine, poverty, and conflict. However, current views highlight the challenges that population growth poses to resources and the environment while discussing approaches to birth control, considering human rights, and the need for complex approaches to addressing these problems.

Some researchers, like Dumont (2001) and Meade et al. (1970), have raised concerns regarding the need for more attention given to population growth in economic discourse. They argue that demographic and economic inquiries are frequently isolated, neglecting vital considerations. These critiques contemplate achieving a more cohesive integration of these pivotal disciplines.

Authors such as Shoven (2010) have highlighted the impact of demographic changes on the sustainability of traditional social security systems and their broader implications for economic growth. Bowen’s (1976) research on mortality, fertility, and migration, as well as Granados’s (2003) interdisciplinary glossary connecting demography, financial history, economic theory, and epidemiology, demonstrate the interconnectedness of these fields.

Understanding the complex interplay between demography and economics is crucial, as Sen (1995) emphasized through his evaluative approach focused on demographics. Wolfson (1955) similarly underscores the significance of demography in economic growth in the literature.

Researchers include Mason (2000), Haines (1987), Schultz (1986), Wenig (1989), Simon (2002), and McDermott (2002) have explored various aspects of this relationship. They have studied the implications of demographic changes on economic growth and behaviors related to fertility and participation in the labor market.

Studies conducted by Sánchez-Romero and colleagues (2018) have found that the demographic transition played a significant role in the increase in per capita income from 1850 to 2000, contributing approximately 17% of the rise. Romero (2011) and Sánchez-Romero (2013) also studied the impact of demographic growth on economic growth, emphasizing the importance of such knowledge in developing effective monetary policies. The notion that demographic growth promotes domestic demand and economic development by increasing labor availability and consumption underlines the positive effects of demographic dynamics.

Hypothesis 3: Increasing population stimulates domestic demand, thus promoting economic growth through increased consumption and available labor.

2. Design research

This research employs advanced econometric methodologies to evaluate the short-term and long-term effects on real estate expansion. It aims to illuminate economic advancements within the MENA region and offer insights into optimal economic and environmental policies conducive to fostering sustainable growth.

Data collection and pre-processing are carried out from reliable sources such as GDP, CO_2 emissions, demographics, and exports, covering the period from 1991 to 2020. Particular attention is paid to pre-treatment to correct any anomalies and ensure the reliability of the time series, using appropriate transformations to ensure their stationarity and linearity.

3. Results and discussion

The specification of the ARDL model carefully determines the optimal number of delays using the AIC or BIC and chooses an appropriate functional form (linear or logarithmic). The minor ordinary squares method (OLS) estimates the model and is supplemented by coefficient stability tests to verify the solidity of the identified relationships.

To confirm the validity and solidity of the results obtained with the ARDL model, a series of stagnation tests (Augmented Dickey-Fuller test, ADF), co-integration tests, and diagnostic tests (verification of heteroscadicity, autocorrelation, and normality of residues) are carried out.

Through its empirical findings based on a rigorous methodology, the study contributes to and has implications for the literature on regional economies. It highlights the significant influence of critical factors on economic growth in the MENA region, providing valuable perspectives for developing policies that promote sustainable development.

The integration of ARDL dynamic simulations and core-based minor regularized squares demonstrates the methodological evolution of this study. These instruments facilitate an in-depth analysis of the effects of denuclearization in Switzerland by providing a precise methodology for their implementation and highlighting their usefulness for formulating specific economic and environmental policies.

According to the ADF test, as illustrated in **Table 1**, the POP and DIRECT_INVES variables are stationary at the level, and the other variables are stable after the first difference.

Table 1. Test of stationarity of the variables.

	At level					
		GDP	**CONS_RE**	**CO_2**	**DIRECT_INVES**	**POP**
With Constant	*t*-Statistic	−1.678258	−1.773167	−0.751143	−1.225277	−1.889227
	Prob	0.430885	0.385357	0.817855	0.648972	0.332057
		n0	*n0*	*n0*	*n0*	*n0*
With Constant & Trend	*t*-Statistic	−1.713044	−1.993954	−2.151969	−3.992572	0.000557
	Prob	0.718492	0.579236	0.496285	0.020484	0.994056
		n0	*n0*	*n0*	**	n0
Without Constant & Trend	*t*-Statistic	−0.809379	−0.773038	−1.588068	0.699532	−3.665511
	Prob	0.356314	0.372216	0.104254	0.860777	0.000707
		n0	*n0*	*n0*	*n0*	***
	At First Difference					
		d(GDP)	*d*(CONS_RE)	*d*(CO_2)	*d*(DIRECT_INVES)	*d*(POP)
With Constant	*t*-Statistic	−2.903099	−2.902838	−3.811348	−9.455928	−3.015537
	Prob	0.057656	0.057687	0.007468	0.000000	0.046064
		*	*	***	***	**
With Constant & Trend	*t*-Statistic	−3.043648	−3.053628	−3.740682	−9.279575	−3.654645
	Prob	0.138881	0.136453	0.035923	0.000000	0.043634
		n0	*n0*	**	***	**
Without Constant & Trend	*t*-Statistic	−2.953037	−2.943540	−3.607281	−9.491859	−1.022048
	Prob	0.004643	0.004758	0.000803	0.000000	0.267799

Similarly, the CUSUM test (which gives an idea of the model's stability), as illustrated in **Figure 1**, confirms the pattern's validity, giving an impression of its stability. It affirms the model's stability (the pattern is inside the two red lines), which means the model Stability (the model is within the two red lines). Cusum squares, as illustrated in **Figure 2**, also approved the same outcome.

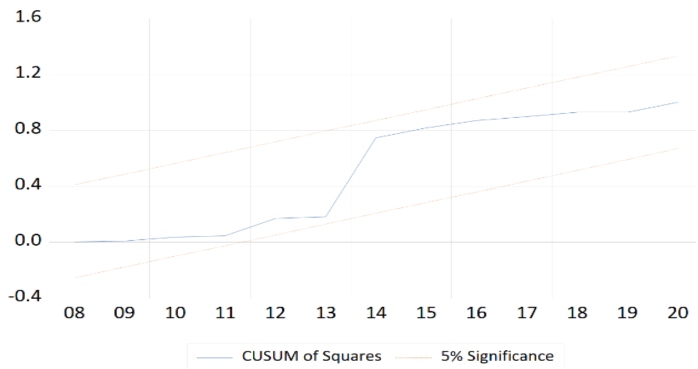

Figure 1. Cusum of squares test for parameter stability.

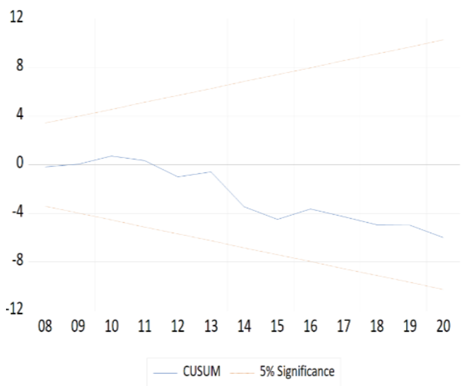

Figure 2. Cusum test for parameter stability.

In **Table 2**, the Jarque-Bera normality test shows that the residuals follow a normal distribution. The Breusch-Pagan-Godfrey heteroscedasticity test indicates that we cannot reject the homoscedasticity hypothesis. Finally, the Breusch-Godfrey serial correlation test shows we must accept the hypothesis of no serial correlation up to three lags.

Table 2. Validation test.

Test	Statistics test	*p*-value	Conclusion
Test of normality: Jarque-Bera	0.266084	0.875428	The residuals are approximately normally distributed, as the high *p*-value prevents us from rejecting the null hypothesis.
Test d'hétéroscédasticité: Breusch-Pagan-Godfrey	*F*-statistic: 1.166491 Obs*R-squared: 14.537450	Prob, F(13,13): 0.392729 Prob, Chi-Square(13): 0.337111	We cannot reject the null hypothesis of homoscedasticity because the *p*-values are more significant than the 0.05 threshold.
Test of serial correlation: Breusch-Godfrey	*F*-statistic: 0.7143969435352899, Obs*R-squared: 1.517076866572133	Prob. F(1,12): 0.4145231091736339, Prob. Chi-Square(1): 0.2180623869643525	We cannot reject the null hypothesis of no serial correlation up to 3 lags, as the *p*-values are more significant than the threshold of 0.05.

As illustrated in **Table 3**, The cointegration test reveals a rejection of the null hypothesis, suggesting cointegration between the variables in the model and, more specifically, that there are four cointegrating variables, indicating a long-term relationship between these variables., indicating a long-term relationship between these variables. Statistical analysis shows a significance of cointegration, illustrated by an F-statistic of 8.453617 and a t-statistic of −4.655758. These values exceed the significance thresholds set at confidence levels of 10%, 5%, and 1%, enhancing the robustness of the cointegration between the variables. By providing these results, the associated critical values allow a direct comparison between observed values and significance thresholds, thereby consolidating the validity of the cointegration analysis.

According to the Akike Information Criterion (AIC), as illustrated in **Figure 3**, among the top 20 models, the ARDL model (1, 2, 3, 0, 3) is the best choice. It is a model with four delays for the endogenous variable, three delays for the first exogenic variable, three delays for the second exogenic variable—no trend; and three lags of the additional exogenetic variable. This specification generated the lowest AIC among the models examined, indicating better data adjustment while the complexity of the model was at an appropriate level.

Table 3. Cointegration test.

Null hypothesis: No levels of relationship
Number of cointegrating variables: 4
Trend type: Unrest. trend (Case 5)
Sample size: 27
Test statistic value
F-statistic 8.453617
t-statistic −4.655758
10% 5% 1%
Sample size *I*(0) *I*(1) *I*(0) *I*(1) *I*(0) *I*(1)
***F*-statistic**
30 3.430 4.624 4.154 5.540 5.856 7.578
Asymptotic 3.030 4.060 3.470 4.570 4.400 5.720
***t*-statistic**
Asymptotic −3.130 −4.040 −3.410 −4.360 −3.960 −4.960

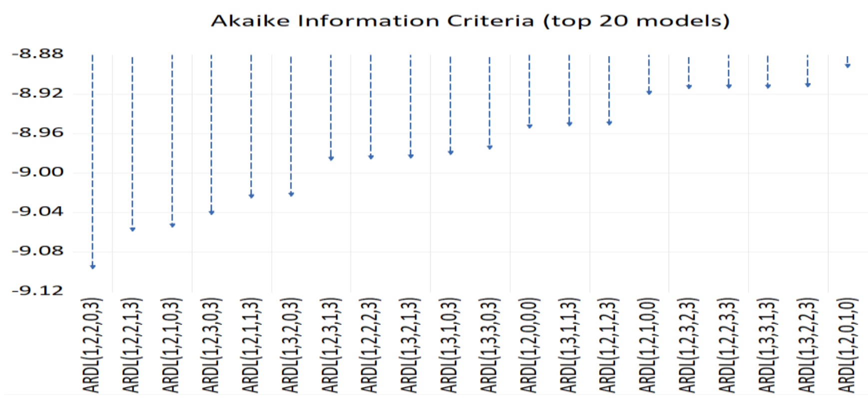

Figure 3. Akaike's information criterion.

After examining the long-term, as illustrated in **Table 4**, consequences of different variables, here is a summary of the observations for each factor taken into account: An earlier increase in consumption is linked to a significant increase in future economic growth, demonstrating a strong direct correlation with an extremely low probability. A preliminary rise in CO_2 emissions leads to a significant decrease in long-term GDP, thus showing a negative link with high statistical significance. An initial increase in population is associated with a subsequent drop in the target variable, leading to a notable negative correlation. The DIRECT_INVES factor does not significantly influence long-term turnover, suggesting that it has no significant impact in this context.

Table 4. Long-term coefficient.

Variable *	Coefficient	Std. error	*t*-statistic	Prob.
CONS_RE(−1)	0.231236	0.008643	26.753260	0.000000
EMISSIONCO2(−1)	−0.691963	0.200506	−3.451077	0.002172
POP(−1)	−0.114351	0.038254	−2.989235	0.006554
DIRECT_INVES	0.000374	0.002643	0.141591	0.888636

The study's findings underscore the significant impact of past changes in consumption, CO_2 emissions, and population on the long-term interest variable. These results align with economic principles and highlight the substantial effects on future growth.

Based on theoretical and empirical debates, adopting renewable energies is posited to spur economic growth. This is due to their reduced environmental impact, contribution to reducing external costs, and resource conservation. Moreover, the evolution of renewable energy technologies fosters innovation and competitiveness.

Investment in renewable energies holds the potential for multiplier benefits for the economy. This could lead to job creation in the energy sector and related sectors such as material manufacturing, construction, and maintenance. Such diversification of employment opportunities can stimulate domestic demand and foster economic growth.

Reducing dependence on fossil fuels, reducing vulnerability to fluctuations in hydrocarbon prices, improving the country's energy security, and reducing the risks associated with energy crises can promote economic stability.

The COINTEQ* variable, as illustrated in **Table 5**, is associated with co-integration error correction. Its negative coefficient, alongside its significant statistical significance, enables the measurement of the pace at which short-term deviations from long-term equilibrium diminish. In the case of short-term imbalances, a negative coefficient indicates that there is a tendency to regain the long-term balance. In this situation, a p-value very close to zero indicates the great significance of this variable.

Table 5. Short-term coefficient.

Variable	Coefficient	Std. error	*t*-statistic	Prob.
COINTEQ*	−0.511907	0.068854	−7.434625	0.000001
D(CONS_RE)	0.206931	0.004207	49.189899	0.000000
D(CONS_RE(−1))	−0.017001	0.005150	−3.300843	0.004222
D(EMISSIONCO2)	−0.038535	0.069969	−0.550739	0.588978
D(EMISSIONCO2(−1))	0.131235	0.066629	1.969646	0.065396
D(POP)	−0.003990	0.016951	−0.235366	0.816737
D(POP(−1))	−0.033160	0.019308	−1.717426	0.104062
D(POP(−2))	0.058658	0.017385	3.374125	0.003604
C	4.669170	0.629518	7.417051	0.000001
@TREND	−0.015241	0.002033	−7.496891	0.000001

The variable D(CONS_RE) represents the first disparity in consumption. The high value of its positive coefficient and its high statistical significance suggest that fluctuations in consumption significantly impact the variable subject to the model. Increasing consumption leads to a significant increase in the dependent variable.

This variable, D(CONS_RE(−1)), captures the lagged impact of a consumption change on the dependent variable. Its negative coefficient and statistical significance suggest that an uptick in consumption in the preceding period correlates with a noteworthy decline in the current dependent variable.

The variable D(POP(−2)) represents the first disparity of the lagging population over two periods. Its coefficient's positive effect and statistical significance suggest a significant impact of the population of the previous two periods on the dependent variable, suggesting that population fluctuations influence the dependent variable, even after some time

This analysis (**Figure 4**), based on a dynamic ARDL model, shows that a positive shock linked to renewable energy consumption leads to an immediate increase in economic growth, stabilizing and remaining sustainable over the long term. In contrast, **Figure 5** illustrates the impact of a shock linked to CO_2 emissions, which causes a significant reduction in economic growth immediately after the shock. Although growth subsequently picks up again, it remains lower than before the shock, indicating a marked but temporary decline in economic growth, followed by a more minor but significant recovery.

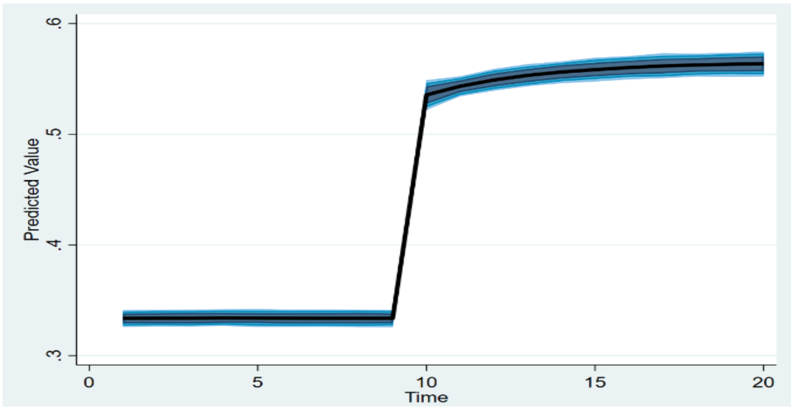

Figure 4. Predicted effects of ±1 standard deviation counterfactual shocks to public attention for renewable energy on economic growth.

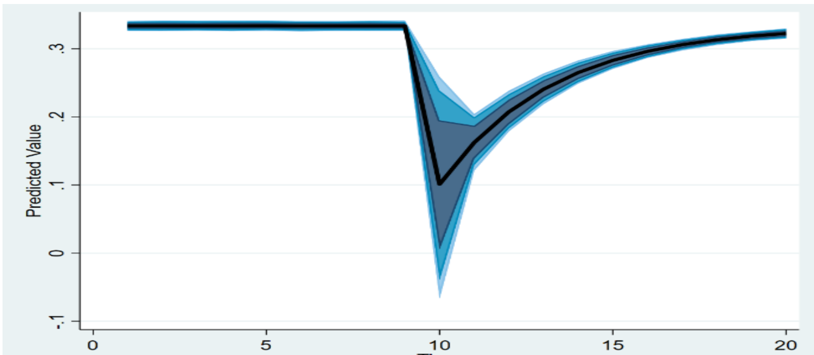

Figure 5. Predicted effects of counterfactual shocks of ±1 standard deviation of public attention to CO_2 emissions on economic growth.

Before the shock, the data in **Figure 6** illustrates a negative correlation between increased CO_2 emissions and GDP, highlighting the economic disadvantages of continued reliance on fossil fuels.

On the other hand, **Figure 7** indicates a significant positive correlation between renewable energy consumption and GDP growth. This relationship suggests that as nations invest more in renewable energy technologies, they may experience economic benefits. The shift towards renewable energy can drive economic growth through several mechanisms.

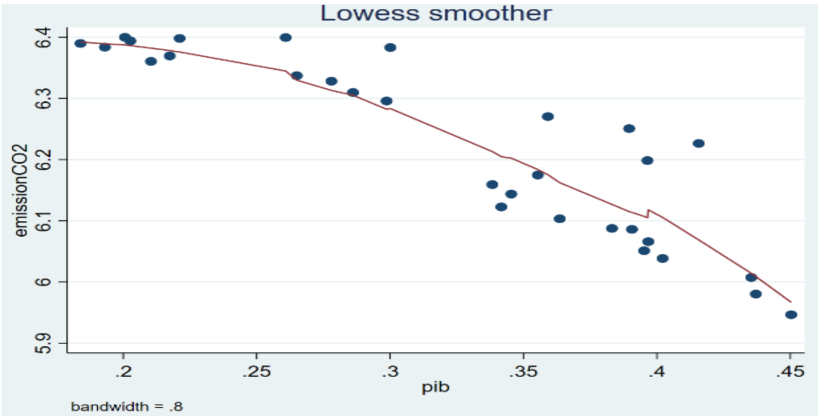

Figure 6. Evolution of CO_2 emissions with economic growth.

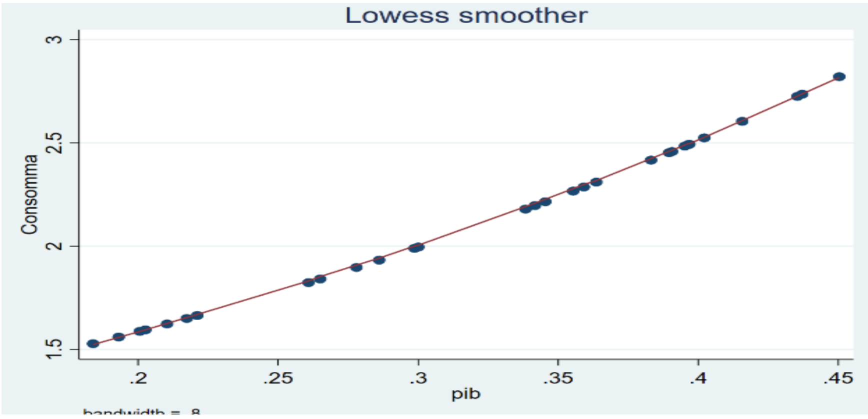

Figure 7. Evolution of renewable energy consumption with economic growth.

3.1. Analysis of ARDL dynamic simulation and shocks during simulations

Effects on gross domestic product (GDP): as illustrated in **Figure 3**, if renewable energy consumption receives a positive and significant coefficient, it signifies that the utilization of renewable energy fosters economic growth. Conversely, a negative coefficient could indicate the opposite effect. Effects on other factors: Besides influencing gross domestic product, an increase in renewable energy consumption can also affect other explanatory variables in our model. For example, this could impact carbon dioxide (CO_2) emissions, the consumption of different resources, or even government policies such as tax incentives for renewable energies.

Sustainability analysis: As renewable energy consumption is often linked to environmental preservation objectives, a significant change in this factor can be interpreted in a broader context of economic and ecological sustainability. This analysis can help assess energy policies and transition strategies towards more environmentally friendly energy sources.

Our model's political and strategic consequences regarding policy and strategy can be considerable. When we see a significant influence of renewable energy consumption on GDP or other economic indicators, it can be of great value to policymakers regarding energy policies, investment, and sustainable development strategies.

When we see a significant change in CO_2 emissions and its temporary impact on GDP, illustrated in **Figure 5**, followed by a return to its original level, while for consumption, the level of GDP changes permanently after the consumptive shock, there are several possible explanations. The shock in CO_2 emissions can cause a temporary fluctuation in GDP, which implies that it has a temporal impact on the level of economic activity. If CO_2 emissions are affected by specific events or temporary fluctuations in economic activities, this can result in a temporary increase or decrease in GDP. On the other hand, change in consumption can have a structural or lasting impact on GDP, which implies that it has a lasting effect on the level of economic activity. GDP can return to its initial level after a CO_2 shock thanks to implementing policies or strategies to mitigate the impact of CO_2 emissions on the economy. For example, to reduce CO_2 emissions and their negative impact on GDP, governments need to take regulatory measures or energy efficiency initiatives. Conversely, the steady fluctuation in GDP after the consumption shock may result from persistent demand for goods and services, favoring sustained economic output over the long term. The reactions of economic actors, such as consumers, can also influence these dynamics. For example, following a consumption crisis, they can modify their production and supply to meet the growing demand for goods and services, resulting in a steady increase in GDP. On the other hand, following a CO_2 shock, companies can implement measures to reduce emissions without changing their production levels permanently. In short, the disparities in GDP responses to CO_2 and consumption shocks can be attributed to temporary or permanent factors, policies and strategies implemented in response to these shocks, and economic actors' reactions to these developments. A thorough study of these elements can help to understand the mechanisms underlying these economic developments.

3.2. Financial considerations and economic benefits associated with the transition to renewable energies in the MENA region, as well as their impact on ecosystems

The transition to renewable energies requires substantial investments in infrastructure, technology, and grid modernization to meet the demands of intermittent energy sources. These investments include acquiring solar panels, wind turbines, energy storage systems, and transmission line upgrades. Morocco, for example, has undertaken considerable investment in solar and wind projects, requiring significant capital to launch these ambitious initiatives (Belaid, 2021; Hamilton, 2020).

In addition, a recent study assessed the economic cost of an energy system based on integrated renewables for the Europe, Eurasia, and MENA regions. With an estimated total cost of around €50/MWh for 2030 cost assumptions, even for higher energy demand, the total LCOE cost would be around €42/MWh, which is lower than coal-CCS or nuclear options. This analysis, carried out by Bogdanov and Breyer (2016), underlines the economic viability of integrated renewable energy systems in these regions.

In addition, a specific study assessed the economic cost of the renewable energy system in the MENA region. The results indicate an initial capital cost of $2615, a current net cost of $53,449, and an energy cost of $0.25 per kWh. This analysis, conducted by Hassan (2021), offers valuable insights into the financial implications of renewable energy initiatives in the region.

The long-term impact of renewable energies on ecosystems:

Renewable energies can have various impacts on ecosystems over the long term. Solar farms, for example, can alter desert ecosystems, grasslands, and farmlands by altering soil composition and water infiltration and affecting native plant species. Similarly, wind farms can disrupt bird migration patterns and bat populations and generate noise pollution in marine and terrestrial environments. Geothermal power plants can influence groundwater resources, local geology, and seismic activity. Hydroelectric dams also have ecological impacts such as habitat loss, fragmentation of river systems, and disruption of fish migration.

3.3. Economic benefits of the renewable energy transition

The transition to renewable energies offers considerable economic benefits that can contribute to sustainable growth and development in the MENA region. Renewable energies have the potential to create local jobs in sectors such as manufacturing, installation, and maintenance, thereby stimulating economic growth. For example, developing wind and solar farms in Jordan has helped create local jobs and strengthen the regional economy (REN21, 2021). By reducing dependence on imported fossil fuels, the transition to renewable energies can improve energy security and reduce energy price volatility, enabling MENA countries to control their energy supply better and reinvest savings in sustainable development initiatives.

Policy recommendations:

Integration with conservation efforts: Renewable energies should be integrated with conservation initiatives to reduce ecosystem impacts. Collaboration with conservation organizations can promote harmonious coexistence with biodiversity.

Promoting research and innovation: Supporting research and the development of innovative technologies is crucial to minimizing environmental impacts and increasing the sustainability of renewable energy projects.

International collaboration and knowledge sharing: Establishing global platforms for sharing best practices and case studies would facilitate knowledge exchange between countries and regions. Capacity building and technology transfer should be encouraged on an international scale.

Increase research and development (R&D) spending: Governments should increase public spending on renewable energy R&D and encourage collaboration between the public and private sectors to stimulate innovation.

Promote public-private partnerships (PPPs): PPPs can be crucial in financing, building, and operating renewable energy projects. Fiscal incentives and transparent regulatory frameworks are needed to attract private investment.

Building local capacity: Investing in training and capacity-building programs is essential to ensure the local workforce has the skills to manage and maintain renewable energy systems.

Creating an enabling environment: Simplifying permitting processes, improving access to finance, and providing technical assistance to project developers are vital to creating an enabling environment for renewable energy development.

Capacity building: Investing in training and education programs to build local capacity in renewable energy technologies can help countries become more self-reliant and sustainably meet their energy needs.

4. Conclusion

Energy is a critical component of the global economy. Its crucial role in development and its links to many aspects of sustainable development are widely recognized. However, most fossil fuels have revealed the resulting environmental consequences, with adverse consequences for society, the economy, and the ecosystem. That is why it is essential to seek green renewable energy sources to reduce pollution and dependence on conventional energies. Renewable energy has gained a reputation as an environmentally friendly and sustainable alternative, becoming a fundamental component of global energy supply. Because of their economic and environmental importance, promoting the development and adoption of renewable energies is essential.

Our research aims to understand how renewable energy consumption, population growth, and exports influence economic growth in the MENA region. After adopting a robust econometric approach based on the ARDL model, we are examining the links between these variables from 1991 to 2020. The information is collected from the World Bank and provided by providers to ensure quality and reliability. In addition, these findings offer concrete insights into the factors that influence economic growth in the MENA region while suggesting policy measures to promote sustainable and inclusive growth.

Limitations of the study:

The study focuses on three decades (1991–2020), but economic and environmental developments are rapid. In future research, it would be possible to extend this analysis period to include more recent data, enabling observation of the impact of recent environmental and economic policies on development.

Restricted variables: The analysis focuses on key elements such as renewable energy consumption, population, and trade. However, it is also possible that other elements, such as technological innovation, the quality of institutions, and investment in research and development, significantly impact economic growth and require further analysis.

While the study delves into an in-depth analysis of the MENA region, caution is warranted when extrapolating its findings to the other areas. Conducting comparative studies across diverse regions would enrich our understanding of how the studied variables impact economic development, considering that the unique characteristics of the MENA region's economies may not be universally applicable. Such cross-regional comparisons further enrich our comprehension of the influence of these variables on economic development.

The study's policy implications underscore the significance of policies that promote renewable energy and environmental management to foster sustainable economic growth. However, a more nuanced examination of specific policies and their efficacy within different national contexts could offer more targeted guidance to policymakers.

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