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Measuring the impact of renewable energy consumption on economic growth in Jordan during the period 1990-2020

Zaynab Hassan Alnabulsi[a*], Salah Turki Alrawashdeh[b], Ahmad Mahmoud Marzouq Abkal, Rafat Salameh Salameh[b*], and Khalid Munther Lutfi[d]

[a]*Assistant Professor, Faculty of Business, Al-Balqa Applied University Jordan*
[b]*Associate Professor, Faculty of Business, Al-Balqa Applied University, Jordan*
[c]*Central Bank of Jordan*
[d]*Cost controller, World Islamic Sciences and Education University Jordan*

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The study aimed to analyze and measure the impact of renewable energy consumption on economic growth in Jordan during the period 1990-2020 using time series analysis; the study tests the stationarity of the time series using the ARDL model. The results show a positive and significant effect of each, renewable energy consumption, gross fixed capital formation, carbon dioxide emissions, and total population, on the real gross domestic product (GDP). The study recommends the importance of government agencies adopting specialized programs in reducing emissions with stakeholders' participation. To work together to spread awareness in this field, limit the spread of these emissions, and ensure that this is a complementary condition for the sectors participating in these programs to obtain funding and provide it over other sectors.

1. Introduction

Production and The issue of climate change and measuring the impact of pollutants on economic growth has become a global issue, preoccupying economists, researchers and decision-makers around the world, this has led to an increase in interest in sustainable development recently, which in turn has become focused on environmentally friendly renewable energy (Usman, Alola, & Sarkodie 2020)., and the world has become in dire need of a new and sustainable financial system to stop the rapid change in climate, which prompted central banks and financial regulators to take into account climate change, we must treat the natural world as we treat the economic world and protect natural capital (International Monetary Fund, 2019). The concept of sustainability in financial institutions includes several dimensions, the most prominent of which are: the financial sustainability of institutions and customers, the economic sustainability of projects and companies, environmental sustainability in preserving natural resources, and social sustainability and its consequences (Islam et al., 2022; Al-Azzam, 2021; Phuong, Duong & Ham,2022). The banking system in Jordan has taken a clear direction towards enhancing the application of the concept of sustainability, as two-thirds of banks in Jordan adopt a sustainability strategy and issue

* Corresponding author
E-mail address zynaba_bau@bau.edu.jo (Z. H. Alnabulsi)

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sustainability reports within the framework of their role in achieving the concept of social responsibility and their support for the sustainability of economic and social growth. This aligns with the United Nations' development goals (Shehadeh, 2017).

Jordan is considered one of the first developing countries to build integrated systems in accordance with international standards to track the reduction of global emissions of greenhouse gases derived from the combustion of fossil fuels or wood, thus raising the phenomenon of global warming and the resulting high temperatures of the air surrounding the earth. Trading in it is part of a pioneering path to address the climate crisis (Ministry of Health, building a resilient and environmentally sustainable health system to confront climate change). A study by the Ministry of Energy and Mineral Resources and the Royal Scientific Society showed that about 16% of Jordan's total land is suitable for wind energy production (Al-Rahahleh, 2018). As for solar energy, the climatic conditions in Jordan are highly suitable for benefiting from solar energy, as the average daily solar radiation ranges between 4 and 7 kWh/m², with about 300 sunny days per year (IRENA, 2021). According to the Ministry of Energy and Mineral Resources, renewable energy contributed to generating electricity by 29% of the electrical energy generated since the beginning of 2022, compared to about 26% during 2021 (Ministry of Energy and Mineral Resources, 2022). Jordan's economy is composed mainly of small and medium-sized enterprises (Alnabulsi et al., 2022) and Since Jordan is one of the energy importing countries, this means increasing the proportion of imported energy to the gross domestic product. Increasing compression on the balance of payments and increasing the government's need to provide foreign currencies continuously to finance energy purchases; means that the search for alternative sources of traditional energy has become necessary, Low costs of technologies have contributed to increasing the portion of renewable energy sources (wind and solar energy) in 2020 causing it to reach 20% of the energy mix (Lutfi et al., 2023).

This study comes to focus in turn on the relationship between the consumption of renewable energy, rather than non-renewable energy, and its impact on economic growth in Jordan during the period 1990-2020, in an attempt to reach results that reinforce this trend and show stakeholders at all levels and in various fields this relationship, which the study hopes to prove to be a positive relationship and its positive impact on sustainable development, economic growth, and an end to pollution in Jordan.

2. The Study hypotheses

Accordingly, the following hypotheses can be formulated for the study:

Ho1: *There is no statistically significant effect of renewable energy consumption on the real GDP*.

Ho2: *There is no statistically significant effect of gross fixed capital formation on real GDP*.

Ho3: *There is no statistically significant effect for carbon dioxide emissions on the real GDP*.

Ho4: *There is no statistically significant effect of the population on the real GDP.*

3. Previous Study

Energy plays a pivotal role in the process of economic growth, so many studies have examined this relationship; among these studies was the study of Adeneye et al. (2021), which examined the dynamic relationships between several variables, including the relationship between energy consumption and economic growth, by using data models of the Joint Dynamic Correlated Effects Panel, in 42 countries during the period 2000-2014. The results indicated relatively high carbon emissions, especially for Asian countries with high population density and geopolitical risks in the short term. The results reveal long-term relationships between the variables attributable to ongoing carbon taxes and energy prices. Benseghier et al. (2021) showed the importance of renewable energy as an alternative energy source for the economic development of Algeria as a feature of sustainable development for the period 1980-2018; the results revealed that the relationship between renewable energy consumption and economic growth is long and short term. The results of the study (Al-Hasanin, 2021) indicated that there is asymmetry or asymmetry in the impact of renewable energy consumption on economic growth in Morocco during the period (1971-2015) and the existence of a causal relationship in one direction between the consumption of renewable energy and economic growth, moving from the consumption of renewable energy to economic growth, which indicates the importance of renewable energy on economic growth in Morocco. Ummalla (2019) aimed to demonstrate the role of natural gas consumption and renewable energy in carbon dioxide emissions and economic growth from 1965 to 2016 in a multivariable framework. The experimental results showed a long-term equilibrium correlation between the variables. Granger's causal results indicate a short-term bidirectional causal relationship between renewable energy consumption and economic growth in India. At the same time, natural gas consumption causes economic growth in China, while in India, there is no proven short-term causal relationship. The results indicated that there is a bidirectional long-term causal relationship between the studied variables in both countries.

Rehman et al. (2019) find that the long-run effects of variables have a more substantial effect on GDP per capita than the short-run dynamics. Evidence suggests that the Pakistan government should promote renewable energy resources to solve the country's energy crisis and introduce new policies to reduce carbon dioxide emissions. Lu (2017) revealed that there is a long-term balance between renewable energy consumption, carbon emissions and GDP. The study showed that carbon dioxide

emissions positively affect the consumption of renewable energy in the Philippines, Pakistan, China, Iraq, Yemen and Saudi Arabia. And renewable energy will increase by 0.64%. When the GDP increases by 1%. This is due to the existence of a two-way causal relationship between CO_2 emissions and renewable energy consumption and between renewable energy consumption and GDP (Turedi, & Turedi, 2021; Kaartemo & Gonzalez-Perez, 2020). A study by Hochman et al. (2017) indicated that the increase in the use of renewable energy and natural gas in the BRICS countries will lead to a reduction in carbon emissions, and that there is an inverse relationship in the short and long term between them, and that the coefficient of economic growth is positive. The study of Al-Assaf and Warrad (2017) came out with several recommendations, including the need to place investments in renewable energy sources at the top of the Board of Investment's priorities and increase the share of renewable energy sources in energy consumption. Findings from Bhattacharya et al. 2016's long-run production elasticity study indicate that renewable energy consumption significantly impacts economic output for 57% of the selected countries.

4. Theoretical framework

The reality of renewable energy consumption in Jordan

The According to the Council of Economic Policies, the average gross domestic product during the period from 2000-2009 was 6.5%, while during the period from 2010-2016, it amounted to 2.5%, the percentage of the total public debt rose to reach about 95% of the GDP at the end of 2016, while it was 61% at the end of 2010; this means that the economic situation in the past decade was characterized by modest economic growth, high public debt burden, and high unemployment rates. To face these challenges and work to restore the financial balance, in 2017, the government took several structural financial measures to collect government revenues amounting to (450) million Jordanian dinars, to gradually reduce public debt ratios, and implement a new system for expenditures and tax exemption (Economic Policies Council, 2018). Energy has played an important role in being able to do this by having an energy system that is sustainable, low-cost, and safe. The cost of energy imports amounted to about 10% of GDP in 2019 (International Renewable Energy Agency (IRENA, 2021), and the average per capita metric ton/carbon dioxide emissions is (2.40) (World Bank), the rate of energy consumption in Jordan was about (1) ton of oil equivalent (ton) per capita annually, according to 2018 data, and this is less than the global average of (1.84) ton. This means that the coming years will witness progress in economic and social development with the continuous increase in energy consumption (Al-Khawaldeh, 2018).

For this reason, attention must be paid to efficiency, energy conservation, good governance, and diversification of energy supply sources, including the use of renewable energies (the European Program for Renewable Energy and Energy Efficiency in Jordan). Solar photovoltaic, wind, hydro, and biogas power plants generated about 13% of the total energy produced in 2019 (IRENA, 2021). On the other hand, the electricity supply generated from solar photovoltaic energy and wind contributed to avoiding the release of about (1.5) million tons of carbon emissions (International Renewable Energy Agency, IRENA, 2021). In general, the International Renewable Energy Agency (IRENA) confirmed that despite the challenges that the supply chain faced recently, the cost of producing electric energy from wind energy decreased by 15% and from solar energy by 13% compared to 2020. The report added that renewable energy added in 2021 saved about $55 billion in global energy generation costs in 2022 in the G20 countries (Babrik, 2022). Hence, renewable energy is the best option in light of these data to combat climate change (Tien & Duong, 2021), especially in Jordan, where solar energy and wind energy are available in Jordan in a way that allows them to be used, as previously mentioned. To protect the environment, strive to achieve sustainable development, and work to reduce the oil bill; the renewable energy strategy has been modified to increase the share of renewable energy in the total energy mix. (Economic Policy Council, 2018). The Jordanian government has implemented its National Energy Strategy for the years 2015-2025, which supports the Kingdom's transformation in the field of energy, seeks to reduce energy costs in Jordan, and provides more energy solutions to be available at reasonable prices for local sectors; this allows them to continue to grow in line with Jordan's economic growth stimulus plan 2018-2022, which aims for renewable energy to produce 10% of the total energy mix by 2020 (Ministry of Energy and Mineral Resources - Annual Report 2017). And since Jordan has a population of more than 11 million people, including more than a million refugees, which increases the demand for energy and the financial burden on the state budget, Jordan sought to enter the carbon markets by adopting a comprehensive, transparent, and climate-friendly investment financing project, to help integrate climate change considerations into the decision-making process. And since Jordan has a population of more than 11 million people, including more than a million refugees, which increases the demand for energy and the financial burden on the state budget, Jordan sought to enter the carbon markets by adopting a comprehensive, transparent, and climate-friendly investment financing project, to help integrate climate change considerations into the decision-making process, enabling the monitoring, reporting and verification system to calculate greenhouse gas emissions reductions for climate-friendly projects and work to find out whether they are eligible to participate in the carbon market, especially since Jordan suffers from a lack of natural resources, most notably water resources (Ministry of Energy and Mineral Resources). Accordingly, Jordan has made great strides in preserving the environment and reducing greenhouse gas emissions. This study provides an econometric analysis of the impact of renewable energy consumption on economic growth in Jordan from 1990-2020. Fig. 1 shows the general trends of the study variables during the study period (1990-2020), where it is clear from the figure that carbon dioxide emissions during the study period were stable despite the noticeable increase in the population and real gross domestic product and somewhat stability in fixed capital formation. It is noted that despite the apparent rise in real GDP, especially in the years 2006-2007, there were no clear correlations through the form of carbon

dioxide emissions with clear economic growth. The figure also shows the apparent growth in the population during the study period, but it was not reflected in the emissions of toxic gases represented by carbon dioxide, which remained somewhat stable during the study period. The figure also shows that investment in renewable energy has started to grow significantly from 2014-2020; this increase came as a response to international agreements related to climate protection; although Jordan is not a source of pollution, this proves that Jordan is a recipient country of toxic gas emissions and not a manufacturer.

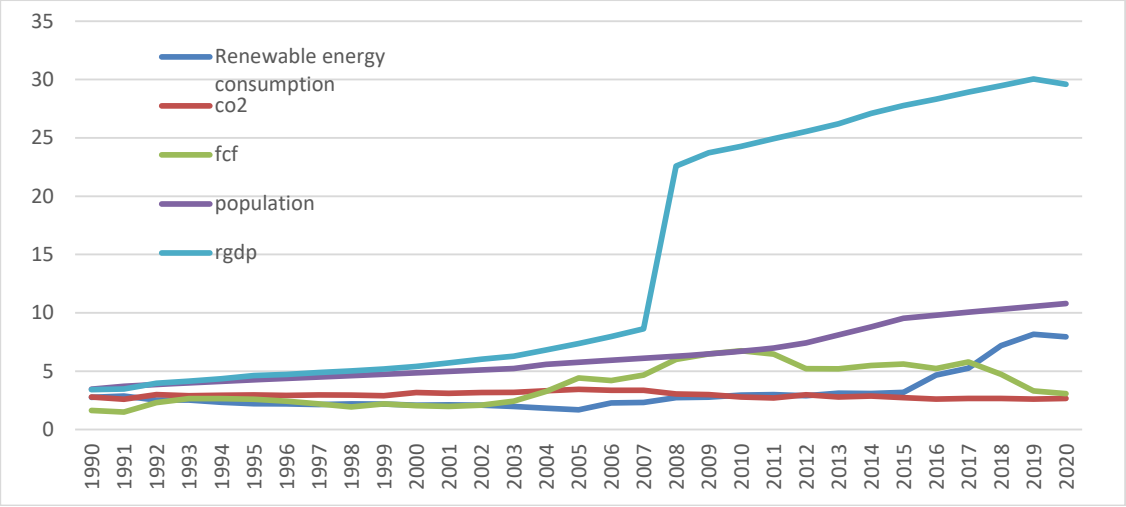

Fig. 1. The general trends of the study variables 1990-2020

Source: From the work of researchers

5. Methodology

The study adopted a standard analysis of the impact of renewable energy consumption on economic growth in Jordan from 1990-2020, using time series analysis. The study examines the stationarity of time series, as the study adopted the ARDL model. This part deals with the following main headings:

- The standard model includes real GDP as a dependent variable, renewable energy consumption, population, carbon dioxide emissions, and fixed gross capital formation as independent variables.
- The inertia test for model variables and the study adopts the extended Dickie-Fuller test as one of the unit root tests to detect the inertia of the time series of model variables.
- ARDL model estimation.

5.1 The standard model

According to the economic theories and models that deal with and interpret real GDP is affected by multiple factors. Therefore, the standard models that link real GDP to other variables must differ. Concerning the impact of each (renewable energy consumption, gross fixed capital formation, carbon dioxide emissions, and total population) on the real GDP, the mathematical relationship between the variables mentioned in Eq. (1) can be written as follows:

$$lRGDP = f\ (\ lRenEnergy, lCO_2, lFCF, lPopulation,\ ) \quad (1)$$

where:

LRGDP: logarithm Real Gross Domestic Product.

LRenEnergy: logarithm Renewable Energy Consumption.

LCO₂: Carbon Dioxide Logarithm

LFCF: Fixed Capital Formation Logarithm

LPopulation: Logarithm Population

Based on the preceding, the model can be written in Eq. (1) in the form of a multiple linear regression equation as in the following Eq. (2):

$$lRGDP_t = \beta_o + \beta_1 lRenEnergy_t + \beta_2 lCO_{2_t} + \beta_3 lFCF_t + \beta_4 lPopulation_t + u_t \quad (2)$$

where β_1, β_2, β_3, β_4 denote the parameters of the independent variables, β_o denotes the segment of the function, and u_t denotes the error term.

5.2 Test the stillness of model variables

One of the crucial issues in the field of econometrics in general and in the field of time series analysis in particular is the stability of these series, whereas, the arrival of these studies to results that may be erroneous will be due to the assumption of stability of variables and conducting appropriate tests. Using the enhanced ADF unit root test the invariance of the time series can be detected. Based on the probability value associated with the t statistic used in the ADF test, a judgment is made on the constant variable time series. There is an indication that the time series of a variable is not stationary if the probability is greater than 5% (Gujarati, 2004). If the degree of inertia in the time series of the variable is fixed at the level, it is indicated by I (0), and if it is constant at the first divergence, then it is indicated by I (1). Table 1 includes the calculated t-statistics and the results of the unit root test (Extended Dickey-Fuller test) for the study variables at the level and the first difference.

Table 1
The results of the ADF unit root test on the variables of the study model, at the level and the first difference

Unit Root Tests at Level Ho: Variable Has A Unit Root				
Variable	Intercept		Decision	
	t-Statistic	Prob.		
LRGDP	-5.106	0.0003	Reject Ho	
LRenEnergy	1.937	0.9996	Failed to Reject Ho	
$lPopulation$	0.473	0.9827	Failed to Reject H_o	
FCF	-1.424	0.5570	Failed to Reject H_o	
CO_2	-2.161	0.2241	Failed to Reject Ho	
Unit Root Tests at First Difference Ho: First Difference of Variable Has A Unit Root				
Variable	Intercept		Decision	
	t-Statistic	Prob.		
LRGDP	-3.952	0.0051	Reject H_o	I(1)
LRenEnergy	-3.568	0.0160	Failed to Reject Ho	I(1)
$lPopulation$	-2.956	0.0512	Failed to Reject H_o	I(1)
FCF	-3.467	0.0165	Reject H_o	I(1)
CO_2	-6.992	0.0000		

It can be seen from Table 1 that all variables of the study model are static at the first difference, and thus the ARDL model can be estimated.

5.3 Estimating the (ARDL) model for the short and long term

First: Estimating the model in the short term (Error Correction Model)

Attention is focused on three criteria when using the ARDL method to estimate the error-corrected model. First, the nature and significance of the dependent variable being affected by the independent variables in the short run. The second is the negative sign of statistical significance and error correction coefficient. The third aspect relates to the absence of legal problems in the model and its quality.

Table 2
Results of Error Correction Model

	Coefficient		**t-Statistics**	**Prob.**
ECM	-0.185		-30.501	0.0000
R^2 = 96 %				
	Diagnostics Tests			
Test	**Null Hypothesis H_0**	**Prob.**	**Sig.**	**Decision**
Breusch-Pagan-Godfrey	No Heteroskedasticity	**0.312**		Failed to Reject H0
Breusch-Godfrey LM Test	No Serial Correlation	**0.319**	**5%**	Failed to Reject H0
Histogram – Normality Test	Residuals are Normally Distributed	**0.929**		Failed to Reject H0

ECM Error Correction Coefficient and Bounds Test

The estimation results show that the error correction coefficient is negative and statistically significant at the 5% significance level; the coefficient's value was (-0.185), and the probability associated with it was (0.00). This result indicates that within about five years the value of the dependent variable in the model deviates from the equilibrium value and is gradually corrected. The statistical value of F was (103.365) according to the results of the F-Bounds test, which means that at the

significance level (1%) the standard value is greater than the upper limit. It turns out that there is a long-term relationship in the study model between the dependent variable and the independent variables, as confirmed by the results.

The quality of the rating and its absence of standard problems

Through the value of the coefficient of determination (R^2) and the significance of the estimated data, the quality of the model can be judged. Most of the estimated data was statistically significant at the 5% level of significance as shown by the results. The relationship between the dependent variable and the independent variables was statistically significant. And the value of the coefficient of determination in estimating the model was (96%), which means that the change in the independent variables was able to explain (96%) of the changes in the dependent variable in the model. The values of the significant probability and the high values of the coefficient of determination reflect the quality of the model, as it can be said, based on these results, that the model is good. The estimate was free from standard problems as shown by the results. This depends on the decision not to reject (accept) the null hypothesis. The absence of standard problems and the quality of the model also supports the adoption of the standard results contained in the analysis of the relationship between variables.

5.3 Rating the model in the long term

According to the (ARDL) methodology, the following Eq. (3) was used to formulate the long-term study model, and Table 3 shows that

$$lRGDP_t = \beta_o + \beta_1 lRenEnergy_t + \beta_2 l\mathrm{CO}_{2_t} + \beta_3 lFCF_t + \beta_4 lPopulation_t + u_t \quad (3)$$

Table 3
The results of the estimation model (ARDL) for the study model

Variable	Coefficient	t-Statistics	Prob.
LRenEnergy	0.106	3.454	0.0062
$\boldsymbol{CO_2}$	1.794	5.873	0.0002
FCF	0.089	2.587	0.0275
$\boldsymbol{lPopulation}$	0.751	3.19	0.0096
C	-2.243	-2.392	0.0378

Based on the results presented in Table 3, the model can be rewritten as in Eq. (4):

$$lRGDP_t = -2.243 + 0.106\, lRenEnergy_t + 1.794\, l\mathrm{CO}_{2_t} + 0.089 lFCF_t + 0.751 lPopulation_t. \quad (4)$$

It should be noted that all the parameters estimated in the study model are statistically significant at the 5% significance level before starting to analyze the results presented in Table 3 about the effect of independent variables on real GDP. The impact of renewable energy consumption on real GDP was positive and significant, as shown by the results. The probability associated with renewable energy was (0.0062), which is significant at a significant level of 1%, and the value of the coefficient associated with renewable energy consumption was (0.106). Gross fixed capital formation has a positive and significant impact on the real GDP, as shown by the results. The probability associated with the total fixed capital was (0.0275), which is significant at the level of significance of 5%, while the value of the coefficient associated with it was (0.089). The effect of carbon dioxide emissions was positive and significant on the real GDP, as the results showed. The probability associated with carbon dioxide emissions was (0.0002), which is significant at the significance level of 1%, while the value of the associated coefficient was (1.794). The impact of carbon dioxide emissions was positive and significant on the real GDP, as the results showed. The probability associated with carbon dioxide emissions was (0.0002), which is significant at the 1% level of significance, while the value of the associated coefficient was (1.794). The effect of the total population is positive and significant on the real GDP, as shown by the results. The probability associated with the total population was (0.0096), which is significant at the 1% level of significance. The associated coefficient was (0.751).

6. Discussion

According to the results, the impact of each (renewable energy consumption, gross fixed capital formation, carbon dioxide emissions, and total population) on the real GDP is positive and significant. To justify the moral impact of renewable energy consumption on real GDP; A study issued by the Jordanian Strategy Forum in August 2018 showed that there is a long-term explanatory relationship between electricity consumption and economic growth. This is consistent with the results of the study by the researchers. A study by Bhattacharya et al. (2016) was also consistent with the study's results, which show a positive impact of renewable energy consumption on the economic output of 57% of the countries selected in the study. The study by Lu (2017) and Hao et al. (2021) concluded that there is a long-term balance between renewable energy consumption, carbon emissions, and GDP, and the existence of two bidirectional causal relationships between carbon dioxide emissions and renewable energy consumption and between renewable energy consumption and GDP. The results are also consistent with the study (Al-Hasanin, 2021; Marinaș et al., 2018), which showed a causal relationship in one direction between the

consumption of renewable energy and economic growth, moving from the consumption of renewable energy to economic growth, which indicates the importance of renewable energy on economic growth. To justify the moral impact of fixed capital formation on real GDP, A study prepared by the Jordan Strategy Forum in June 2017 showed the importance of companies investing in fixed assets due to its positive impact on their financial performance and thus on economic growth and this is consistent with the results of the study of this effect that the researchers reached. According to the findings of the study by Rehman et al. (2019) and Xie et al. (2020), the long-term effects of variables have a more substantial effect on GDP per capita than the short-term dynamics as well as the study of Al-Assaf and Warrad (2017), which showed the need to put investments in renewable energy sources at the top of the priorities of the Investment Council and increase the share of renewable energy sources in energy consumption. In order to justify the positive and significant impact of carbon dioxide emissions on the gross domestic product, a study issued by the Economic Visions magazine in December 2021 showed that there is a direct relationship between carbon dioxide emissions and electric energy consumption with the gross domestic product in the long term, this is consistent with the result of the study for this effect that the researchers reached. The study also came in agreement with the study of Hochman & Sun Dong (2017) and Soava et al. (2018), which showed that the increase in the use of renewable energy and natural gas in the BRICS countries would lead to a reduction in carbon emissions, where the study showed that there is an inverse relationship in the short and long term between them and that the coefficient of economic growth was positive. The results of the study are also consistent with the study Lu (2017), Zhe et al. (2021) and Derrick et al. (2021) which concluded that there are two bidirectional causal relationships between carbon dioxide emissions and renewable energy consumption and between renewable energy consumption and GDP, in addition to the existence of a long-term balance between renewable energy consumption and carbon emissions and GDP.

In order to justify the positive and significant impact of population on economic growth, a study issued by the International Society for Industrial Engineering and Operations Management in 2021 showed that there is a positive and significant impact of population growth on economic growth; this is consistent with the result of the study for this effect that the researchers reached. It agrees with the study of Benseghier et al. (2021) and Muazu et al. (2023), which showed the importance of renewable energy as an alternative energy source for the economic development of Algeria as a feature of sustainable development. The researchers hope that this study's results will help decision-makers develop an appropriate policy to conserve energy, reduce waste and increase investment in renewable energy for low-carbon growth. Based on these results, the study recommends the importance of government agencies adopting specialized programs in the field of reducing emissions with the participation of stakeholders to work together to spread awareness in this field and limit the spread of these emissions, emphasizing that this is a complementary condition for the sectors participating in these programs to obtain funding and to provide it over other sectors, as well as activating and generalizing the principle of "joint responsibility and win-win for all partners" in the field of reducing emissions, in addition to coordinating efforts at all local, regional and international levels to transfer expertise and support programs supporting emissions mitigation and development. In addition, the legislative framework and the appropriate legal umbrella are put in place to ensure the implementation of emissions mitigation programs and their funding from donors. The researchers also recommend the importance of conducting future studies dealing with the same topic, but in other time periods or in the same period for neighboring countries.

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