Journal of contemporary economic research **ISSN 2623-2602/ EISSN: 2716-8891**
Vol 09 **, N°:** 2 **(2026), p** 21-38

Analyzing the Causal and Dynamic Relationship between Renewable Energy Indicators and Economic Growth in Algeria: An Econometric Study Based on the VAR Model and Granger Causality Test.

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Received: 7/31/2026 **Accepted**: 10/29/2026 **Published**: 11/4/2026

Abstract:

The study aims to analyze the dynamic relationship between renewable energy and economic growth in Algeria over the period 1990–2025 using the Vector Autoregression (VAR) model and the Granger causality test.

The findings from the impulse response function analysis reveal a dynamic interaction between renewable energy variables and economic growth, although the intensity of this interaction varies. The results indicate that improvements in Algeria's economic growth contribute to increased investment in and demand for renewable energy. However, the contribution of the renewable energy sector to economic growth remains limited. Furthermore, the study identifies a unidirectional causal relationship running from economic growth to renewable energy, while no strong or statistically significant causal relationship is found from renewable energy to economic growth.

Keywords: Renewable Energy, Economic Growth, VAR Model,
JEL Classification Codes : **C32** ; **O44**

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1. INTRODUCTION

Over the past decades, the energy sector has undergone profound transformations at the global level, driven by growing concerns over energy security, sustainable development, and climate change. Consequently, most countries have adopted strategies and policies aimed at promoting the use of renewable energy sources and reducing the unsustainable dependence on depleting fossil fuel resources, in response to the environmental and economic challenges arising from the rapidly increasing demand for energy. In this context, renewable energy has emerged as one of the cleanest and most sustainable sources of energy, while also representing a viable and economically competitive alternative to conventional energy systems.

Accordingly, interest in renewable energy is no longer confined to its role in mitigating the adverse effects of climate change; it has expanded to encompass its contribution to economic growth and sustainable development. Investments in clean energy technologies have become one of the principal drivers of economic activity by stimulating investment, diversifying energy sources, creating employment opportunities, fostering innovation, and improving the efficiency of resource utilization. Moreover, these technologies have contributed to providing affordable and accessible energy solutions, particularly in regions suffering from inadequate energy services, thereby enhancing equitable access to energy and supporting comprehensive sustainable development efforts.

Numerous empirical studies, drawing on the experiences of countries such as Germany, Denmark, Brazil, and India, have confirmed that the adoption of supportive renewable energy policies has contributed to achieving higher rates of economic growth while simultaneously mitigating the environmental problems associated with the use of fossil fuels (Fang, 2023). These experiences further demonstrate that investment in renewable energy is not merely a response to environmental challenges; rather, it represents a genuine economic opportunity to enhance the competitiveness of national economies, improve air quality, reduce dependence on imported fossil fuels, strengthen energy security, and improve the trade balance. These benefits are particularly significant for energy-importing countries (M.Z. & M.A. , 2011).

Conversely, although the intensive reliance on fossil fuels has been one of the primary drivers of economic growth over the past decades, it has also led to increased carbon dioxide (CO_2) emissions, the intensification of global warming, and environmental degradation. These consequences have given rise to significant challenges that threaten the sustainability of economic development and the well-being of future generations (P, V, O., & N., 2020) . From this perspective, renewable energy has emerged as one of the most important strategic options for

achieving a balance between the requirements of economic growth and environmental protection (Sikder , Inekwe, & Bhattacharya, 2019).

The findings of numerous empirical studies indicate the existence of a positive relationship between renewable energy consumption and economic growth. However, the strength of this relationship varies according to countries' levels of economic development. Empirical evidence suggests that the association between renewable energy consumption and economic growth is stronger in countries with higher gross domestic product (GDP) than in low-income economies. Furthermore, econometric analyses reveal the existence of a long-run linear effect of energy consumption on economic activity. In the short run, renewable energy consumption and electricity generation from renewable sources exhibit a positive and statistically significant impact on economic growth in many countries, reflecting the increasingly important role of renewable energy in supporting economic performance. (Akadiri , Alola , Akadiri , & Alola , 2019)

In Algeria, the economic structure is characterized by its strong dependence on the hydrocarbon sector, which constitutes the primary source of public revenues and export earnings. However, the persistent volatility of oil prices, together with environmental challenges and international commitments to reducing carbon emissions, has made the diversification of energy sources a strategic necessity for ensuring sustainable economic growth. Accordingly, Algeria has initiated a series of programs and projects aimed at exploiting its substantial potential in solar and wind energy in order to increase the contribution of renewable energy to the national energy mix and reduce dependence on fossil fuels.

Despite these efforts, assessing the actual impact of renewable energy on economic growth in Algeria still requires further econometric studies that examine the nature of the relationship between renewable energy production and gross domestic product (GDP). This issue extends beyond verifying the existence of a statistical association between the two variables to determining the direction of causality between them, which constitutes one of the fundamental concerns in econometric analysis. Identifying whether an increase in renewable energy production leads to economic growth or whether economic growth stimulates the expansion of renewable energy production would provide valuable insights for formulating more efficient and effective energy and economic policies.

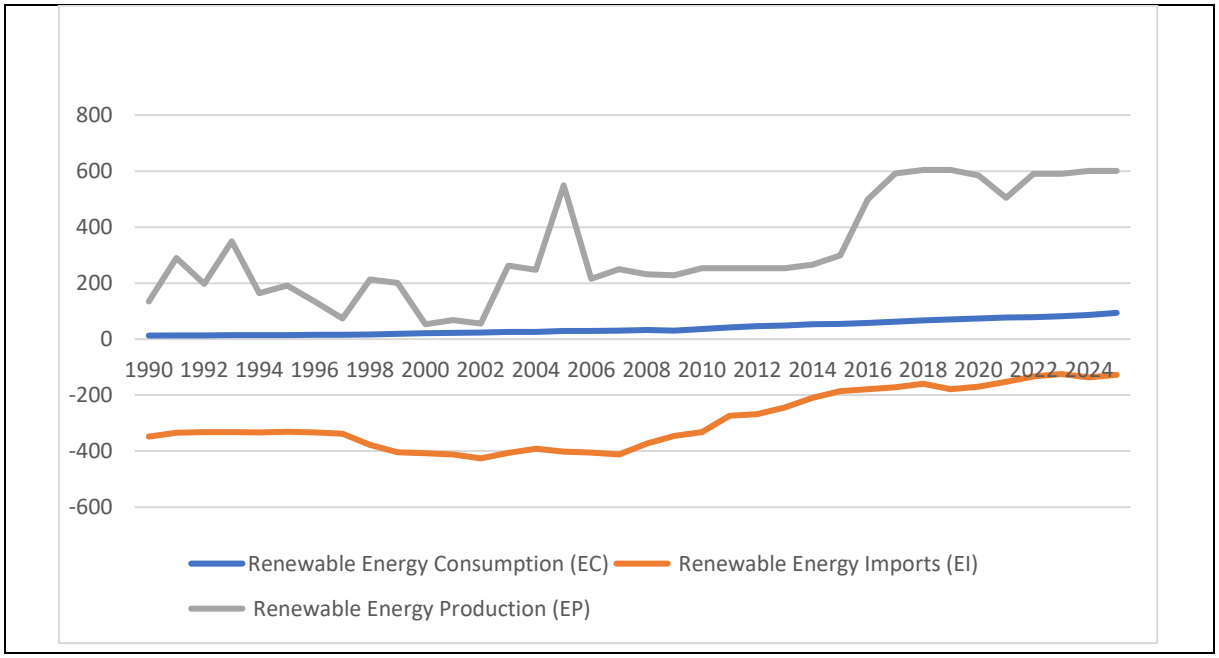
Based on the foregoing, this study seeks to analyze the causal and dynamic relationship between renewable energy production and economic growth in Algeria over the period 1990–2025 by employing modern econometric techniques to address the following main research question:

What is the nature of the causal relationship between renewable energy production and economic growth in Algeria during the period 1990–2025?

2. The Relationship Between Renewable Energy Variables and Economic Growth in Algeria

To investigate the existence of a dynamic relationship between renewable energy production and economic growth in Algeria, this study first examines the trends of the independent variables and the dependent variable, gross domestic product (GDP), over the period 1990–2025. The analysis is based on the following independent variables: renewable energy production, measured in gigawatt-hours (GWh); energy demand, proxied by electricity consumption and measured in gigawatt-hours (GWh); and net energy imports. The corresponding trends of these variables are illustrated in the following figures.

Fig.1. Trends in Renewable Energy Variables in Algeria



Source: Prepared by the author based on IRENA data

The graphical representation shows that renewable energy variables in Algeria experienced uneven developments over the study period. Renewable energy production was characterized by low output and considerable fluctuations during the period 1990–2000. It reached its peak in 1993 before declining sharply by 2000, reflecting its almost complete reliance on hydropower generation and its vulnerability to climatic fluctuations. During the period 2001–2010, renewable energy production exhibited a relative improvement compared with its level in 2000; however, it remained limited and unstable. Between 2011 and 2015, production continued to fluctuate despite reaching relatively higher levels, indicating the persistent influence of natural factors alongside the initial integration of modern renewable energy technologies. A substantial transformation became evident during the period 2016–2020, when renewable energy production increased markedly following the effective deployment of solar energy. This

upward trend continued throughout 2021–2024, reaching its highest level in 2024, thereby reflecting Algeria's transition from a system primarily dependent on hydropower to one characterized by renewable energy production increasingly driven by solar energy. As for energy demand, it exhibited a continuous upward trend throughout the study period. During 1990–2000, energy demand increased at a relatively moderate pace, followed by a more pronounced acceleration during 2001–2010, driven by the expansion of economic activity, rising income levels, and the growing reliance on electricity. Over the period 2011–2020, electricity consumption nearly doubled as a result of population growth, urban expansion, and improvements in living standards, accompanied by an increasing dependence on electricity as the primary source of final energy consumption. This upward trend continued throughout 2021–2024, confirming the sustained growth in energy demand alongside the continued expansion of economic activity.

With regard to net energy imports, the indicator remained negative throughout the period 1990–2023, confirming that Algeria has consistently been a net energy exporter, with energy exports exceeding imports over the entire study period. During 1990–2000, the country recorded a substantial energy surplus, primarily supported by oil and natural gas exports. However, this surplus gradually declined over the period 2001–2010 as a result of rising domestic energy consumption. The same trend persisted during 2011–2014, reflecting increasing internal pressure on energy resources. Between 2015 and 2023, the energy surplus continued to shrink, albeit with some fluctuations, indicating that Algeria maintained its status as a net energy exporter, although with a smaller surplus than that observed during the 1990s.

These developments indicate that renewable energy production remained low and highly volatile until 2010, while gross domestic product (GDP) continued to grow, largely driven by the hydrocarbon sector. This suggests a weak apparent relationship between the two variables during this period. However, the marked increase in renewable energy production since 2015 has coincided with an improvement in economic activity, indicating the emergence of a weak to moderate positive relationship between renewable energy production and economic growth. Nevertheless, this relationship remains limited due to the relatively small contribution of renewable energy to Algeria's national energy mix. In contrast, electricity consumption, used as a proxy for energy demand, increased by more than sixfold over the study period, reflecting a strong positive relationship between energy demand and economic growth. Furthermore, economic growth was accompanied by rising domestic energy consumption, which reduced the energy surplus available for export, thereby indicating an indirect negative relationship between net energy imports and economic growth.

3. Results of the Econometric Analysis of the Dynamic Relationship Between Renewable Energy Variables and GDP

3.1 Definition and Measurement of the Study Variables

To identify the key variables included in this study, the selection of variables is based on the empirical studies conducted by (OZKAN , OZKAN , & KUYUK,, 2012) and (S. H, 2006) both of which examined the relationship between renewable energy and economic growth from different perspectives. The analysis covers the period 1990–2025. The data were obtained from the International Renewable Energy Agency (IRENA)**.** Accordingly, the econometric model can be specified as follows:

$$\boldsymbol{GDP = f(EP, EC, EI)}$$

Where:

- GDP:denotes the dependent (endogenous) variable in the model and represents Gross Domestic Product.
- EP: denotes the first independent (explanatory) variable in the model and represents renewable energy production.
- EC: denotes the second independent (explanatory) variable in the model and represents renewable energy consumption.
- EI: denotes the third independent (explanatory) variable in the model and represents renewable energy imports.

3.2 Stationarity Testing and Optimal Lag Length Determination

To examine the stationarity of the time series for the economic variables, the Augmented Dickey–Fuller (ADF) test**,** developed by Dickey and Fuller (1981), was employed. The test was conducted at the 5% significance level, and the results are presented as follows:

3.2.1 Stationarity Testing

Table 1. Stationarity Testing at Different Levels of Integration

Level											
variable	**Lag**	**Trend and intercept**				**Intercept**				**None**	
		t-statistic	prob	t-statistic	prob	t-statistic	prob	t-statistic	Prob	t-statistic	Prob
GDP	1	3,111	0,0041	2,973	0,154						
EP	2	2,709	0,0114	2,856	0,183						
EC	1	1,803	0,08	1,803	0,561	0,542	0,591	3,624	1,000	5,234	1,000
EI	2	2,343	0,026	2,015	0,571						

1st difference											
GDP		0,912	0,368	3,098	0,123	2,661	0,012	2,968	0,048		
EP		1,08	0,287	4,065	0,016	0,716	0,479	3,91	0,05	3,88	0,00
EC		3,071	0,004	3,577	0,047						
EI		0,839	0,408	2,009	0,573	0,75	0,457	1,846	0,35	1,698	0,08
2nd difference											
EI		0,296	0,769	4,193	0,012	0,064	0,949	4,262	0,002	4,340	0,00

Source: Prepared by the author based on EViews output

As shown in the table above, based on the methodology proposed by Dolado, Jenkinson, and Sosvilla-Rivero (1990), the stationarity analysis indicates that most of the time series are integrated of order one, I(1)**.** However, the variable EI (renewable energy imports) is integrated of order two, I(2)**.** Consequently, the Vector Autoregression (VAR) model is adopted for the empirical analysis.

The VAR model is one of the most widely used econometric approaches for examining the dynamic relationships among economic variables. It explains each endogenous variable by its own lagged values as well as the lagged values of the other endogenous variables included in the system. In other words, the VAR model consists of a system of equations in which each endogenous variable is expressed as a linear function of its own past values and those of the other variables. In time-series econometric analysis, ensuring the stationarity of the variables is a fundamental prerequisite, as it constitutes a basic assumption for the specification and estimation of such models.

3.2.2 Optimal Lag Length Selection

To determine the optimal lag length for the Vector Autoregression (VAR) model, a set of information criteria was employed, including the Akaike Information Criterion (AIC)**,** the Schwarz Criterion (SC), and the Hannan–Quinn Criterion (HQ)**.** The optimal lag order is selected based on the minimum value of these information criteria.

Table 2. Optimal Lag Length Selection Results

Lag	AIC	SC	HQ
0	46,89	47,07	46,95
1	*37,58	*38,48	*37,88
2	37,77	39,40	38,32
3	37,79	40,15	38,58

Source: Prepared by the author based on EViews output

As shown in Table 2, the results indicate that all the information criteria consistently select the first lag as the optimal lag length, as denoted by the asterisk (*). Accordingly, a VAR(1) model, which incorporates one lag, was selected for the empirical analysis.

4. Model Estimation and Model Diagnostic Tests

4.1 Model Estimation

After determining the optimal lag length of one, VAR(1**)**, the model was estimated using annual data covering the period from 1990 to 2025, with a total of 35 observations, in order to examine the dynamic relationships among the study variables, namely: Gross Domestic Product (GDP), Renewable Energy Production **(**EP**),** Energy Consumption (EC), and Energy Imports (EI**)**.

The VAR model equations were estimated using the Ordinary Least Squares (OLS) method by estimating a separate equation for each endogenous variable while incorporating one lag for all endogenous variables. Accordingly, each variable is explained by its own lagged values as well as the lagged values of the other endogenous variables. The estimation results are presented in Table (3) and are expressed through the estimated equations of the VAR(1) model.

Table 3. Estimation Results of the VAR(1) Model

Vector Autoregression Estimates
Date: 05/04/26 Time: 13:28
Sample (adjusted): 1991 2025
Included observations: 35 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	GDP	EP	EC	EI
GDP(-1)	0.987177	0.025410	0.001295	0.014251
	(0.05407)	(0.03928)	(0.00068)	(0.00702)
	[18.2581]	[0.64696]	[1.89798]	[2.03008]
EP(-1)	-0.539142	0.341346	-0.001751	-0.027237
	(0.23255)	(0.16893)	(0.00293)	(0.03019)
	[-2.31837]	[2.02065]	[-0.59696]	[-0.90206]
EC(-1)	8.695649	0.365755	0.950405	-0.584505
	(5.45169)	(3.96018)	(0.06877)	(0.70783)
	[1.59504]	[0.09236]	[13.8192]	[-0.82577]
EI(-1)	-0.763593	0.573469	0.005270	0.972844
	(0.54752)	(0.39773)	(0.00691)	(0.07109)
	[-1.39463]	[1.44187]	[0.76303]	[13.6850]
C	-158.0243	221.3227	-1.404699	-55.91682
	(246.562)	(179.106)	(3.11042)	(32.0127)
	[-0.64091]	[1.23571]	[-0.45161]	[-1.74671]
R-squared	0.995245	0.757388	0.995934	0.975349
Adj. R-squared	0.994611	0.725039	0.995392	0.972062
Sum sq. resids	539106.2	284473.9	85.79498	9087.986
S.E. equation	134.0530	97.37794	1.691104	17.40497

Source: Prepared by the author based on EViews output

The estimation results of the VAR(1) model indicate that the lagged value of Gross Domestic Product, GDP(-1)**,** has a positive and statistically significant effect on its current value, with an estimated coefficient of 0.987 and a t-statistic of approximately 18.26**,** reflecting a strong degree of persistence in GDP. In contrast, the lagged value of Renewable Energy Production, EP(-1)**,** exerts a negative and statistically significant effect on GDP, with a coefficient of −0.539 and a t-statistic of −2.32, indicating an inverse relationship between the two variables. On the other hand, neither EC(-1) nor EI(-1) exhibits a statistically significant effect at the 5% significance level, with t-statistics of 1.60 and −1.39, respectively. Likewise, the constant term is not statistically

significant. The coefficient of determination (R^2) is 0.995245, indicating that the model explains approximately 99.5% of the variation in GDP, thereby demonstrating a very high explanatory power.

Regarding the Renewable Energy Production equation, the results reveal that EP(-1) has a positive and statistically significant effect on its current value, with an estimated coefficient of 0.341 and a t-statistic of approximately 2.02**,** suggesting a considerable degree of persistence in renewable energy production. By contrast, the lagged variables GDP(-1)**,** EC(-1)**,** and EI(-1) are not statistically significant, implying that their effects on renewable energy production are limited. The coefficient of determination **(**R^2**)** equals 0.757388, indicating that the model explains approximately 75.7% of the variation in renewable energy production, reflecting an acceptable explanatory performance.

The estimation results for the Energy Consumption equation show that EC(-1) has a positive and highly significant effect on its current value, with an estimated coefficient of 0.950 and a t-statistic of approximately 13.82, indicating strong persistence in energy consumption. Furthermore, GDP(-1) exerts a relatively weak positive effect on energy consumption, with a t-statistic of approximately 1.90**,** which is close to the 10% significance level**.** However, neither EP(-1) nor EI(-1) has a statistically significant effect on energy consumption. The coefficient of determination (R^2) is 0.995934**,** implying that the model explains approximately 99.6% of the variation in energy consumption, which confirms its excellent explanatory power.

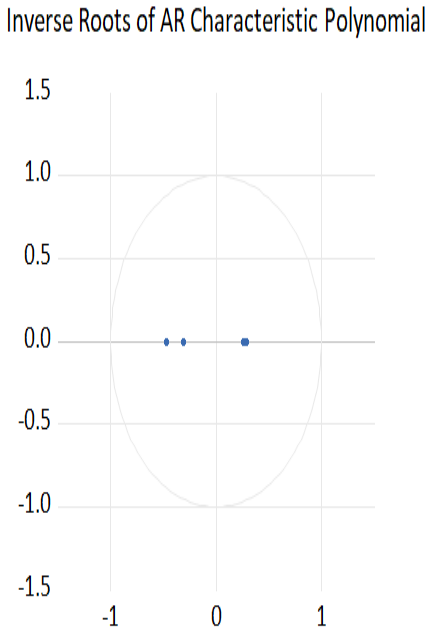
Finally, the results indicate that EI(-1) has a positive and statistically significant effect on its current value, with an estimated coefficient of 0.973 and a t-statistic of approximately **13.69**, reflecting strong persistence in energy imports. Moreover, GDP(-1) has a positive and statistically significant effect on energy imports, with a t-statistic of approximately 2.03. In contrast, EP(-1) and EC(-1) do not exhibit statistically significant effects on energy imports. The coefficient of determination (R^2) is 0.975349, indicating that the model explains approximately 97.5% of the variation in energy imports, thereby demonstrating a high explanatory power.

4.2 Model Diagnostic Tests

After estimating the VAR(1) model, the model stability was assessed using the Inverse Roots of the Autoregressive Characteristic Polynomial test. This diagnostic is based on the fundamental condition that all inverse roots must lie inside the unit circle, meaning that their absolute values are less than one. Satisfying this condition confirms that the estimated VAR model is dynamically stable and free from explosive behavior in the time series, thereby ensuring the validity and reliability of the model for subsequent analysis and forecasting.

4.2.1 Inverse Roots of the Autoregressive Characteristic Polynomial Test

After estimating the VAR(1) model, its stability was assessed using the Inverse Roots of the Autoregressive Characteristic Polynomial Test**.** This diagnostic is based on the fundamental condition that all inverse roots must lie inside the unit circle, meaning that their absolute values are less than one. Satisfying this condition confirms the dynamic stability of the model and indicates the absence of explosive behavior in the time series.

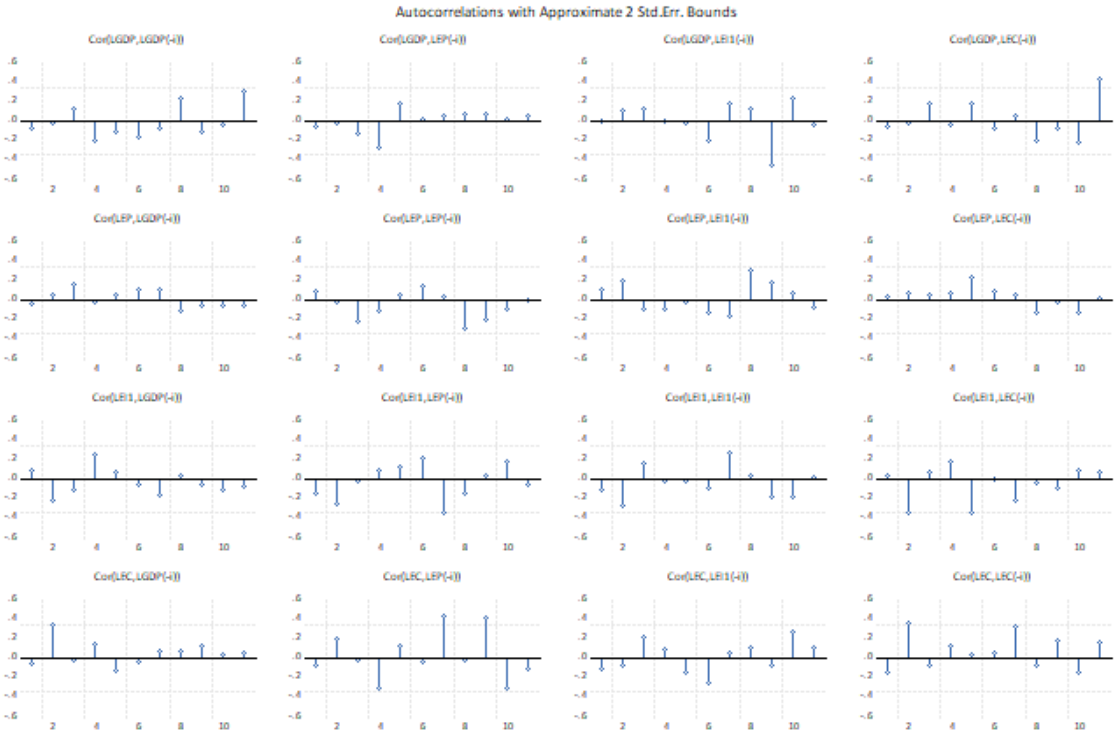


As shown in the figure, all inverse roots are located within the unit circle, confirming that the estimated VAR(1) model satisfies the stability condition. This implies that the dynamic relationships among energy production, energy demand, and energy imports are stable over time, and that the model is appropriate for subsequent econometric analyses, including Granger causality tests, impulse response functions, and forecast error variance decomposition. Consequently, the estimated coefficients are considered reliable, and the model provides a valid basis for interpreting the dynamic interactions among the variable

 ISSN 2623-2602/ EISSN: 2716-8891

4.2.2 Residual Diagnostic Tests

Fig.2. Correlogram of Residuals



Source: Prepared by the author based on EViews output

The correlogram of the model residuals indicates that most of the simple autocorrelation coefficients are not statistically different from zero at the 5% significance level, with the majority of the values lying within the confidence bounds. This suggests the absence of significant serial correlation among the residuals across the different lag lengths. Although a few coefficients exhibit slight deviations at certain lags, these departures are limited and irregular, and therefore do not indicate a systematic pattern of serial correlation. Consequently, the residuals can be considered to behave as white noise, confirming that the estimated VAR(1) model satisfies the residual diagnostic requirements and is appropriate for reliable statistical inference and subsequent dynamic analysis.

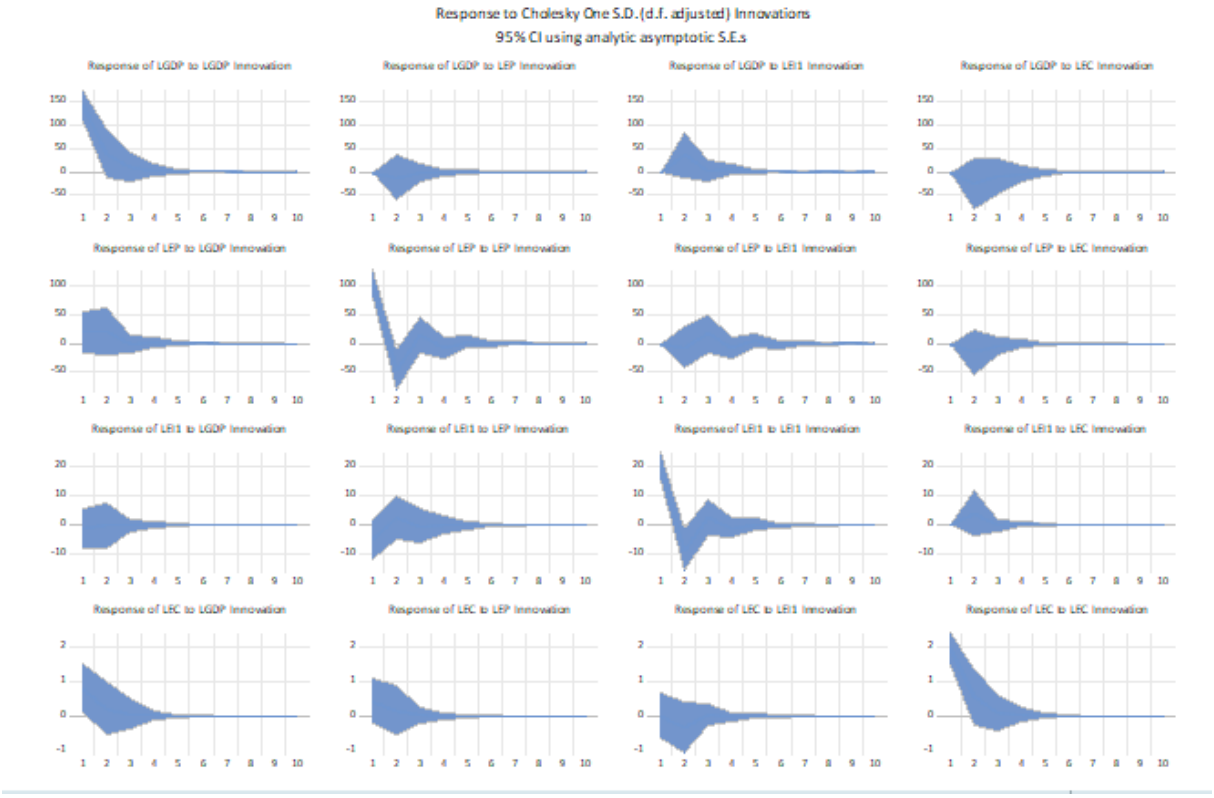
Accordingly, it can be concluded that the estimated VAR model exhibits a satisfactory level of statistical adequacy and diagnostic reliability. The absence of significant serial correlation in the residuals indicates that the model has successfully captured the dynamic causal relationships among GDP**,** EP**,** EC**,** and EI, without leaving any systematic information unexplained. Therefore, the estimated model can be considered statistically valid and suitable for economic analysis, providing a reliable basis for

interpreting the dynamic interactions among the variables and for drawing robust empirical conclusions

5. Analysis of the Causal and Dynamic Relationships among the Variables

5.1 Impulse Response Function Analysis

Fig.3. Figure illustrating the impulse responses of the variables to one-standard-deviation shocks



Source: Prepared by the author based on EViews output

Table 4. Impulse Response Function Results of the Variables

		Period 1		Period 2	
Variables	Shock Origin	Statistically Significant Response	Standard Deviation	Statistically Significant Response	Standard Deviation
LGDP	LGDP	142,98	17,60	38,11	27,15
LGDP	LEP	0,00	0,00	12,83-	24,83
LGDP	LEI1	0,00	0,00	35,58	25,37
LGDP	LEC	0,00	0,00	24,66-	27,65
LEP	LGDP	19,54	18,16	20,73	20,84
LEP	LEP	103,39	12,73	46,75-	18,51
LEP	LEI1	0,00	0,00	6,34-	18,32
LEP	LEC	0,00	0,00	14,76-	20,31
LEI1	LGDP	1,039-	3,572	0,088-	4,038

LEI1	LEP	4,916-	3,518	2,508	3,772
LEI1	LEI1	910, 19	2,451	8,478-	3,748
LEI1	LEC	0,00	0,00	3,894	3,976
LEC	LGDP	819, 0	0,363	0,231	0,405
LEC	LEP	0,442	0,344	0,172	0,375
LEC	LEI1	011, 0	0,340	0,346-	0,387
LEC	LEC	1,952	0,240	0,556	0,421

Source: Prepared by the author based on EViews output

The results of the impulse response functions indicate that gross domestic product (LGDP) responds strongly, positively, and statistically significantly to its own shock during the first period, with a response value of (142.98) and a standard deviation of (17.60)**,** reflecting the existence of an immediate and strong endogenous effect. However, this effect gradually declines over subsequent periods, as the response decreases to **(**38.11**)** in the second period**,** (10.57) in the third period, and (2.71) in the fourth period, becoming statistically insignificant from the fourth period onward. This suggests that the impact of the shock is temporary and gradually dissipates over time. Furthermore, LGDP does not exhibit any statistically significant response to shocks affecting the energy-related variables (LEP, LEI1, and LEC), indicating weak causal effects of these variables on LGDP.

Regarding the energy production variable (LEP)**,** the results reveal the absence of significant responses to shocks originating from other variables (LGDP, LEI1, and LEC), as the responses remain within statistically insignificant bounds, reflecting the lack of clear external effects. Conversely, LEP exhibits a positive and statistically significant response to its own shock in the first period, reaching (103.39) with a standard deviation of (12.73)**.** This response then turns negative and statistically significant in the second period, amounting to (-46.75) with a standard deviation of (18.51)**,** before the effects of the shock gradually vanish from the third period onward. This behavior reflects a strong short-term self-dependence of LEP, accompanied by a rapid adjustment following the shock.

For the variable LEI1**,** the impulse response functions show no statistically significant effects resulting from shocks to LGDP, LEP, and LEC. In contrast, LEI1 displays a strong response to its own shock, recording a positive and statistically significant response of **(**19.91**)** in the first period with a standard deviation of **(**2.45**)**. This response subsequently reverses to a negative value of (-8.48) in the second period, with a standard deviation of **(**3.75**)**, before gradually disappearing from the third period onward.

As for the variable LEC, it exhibits a very limited response to external shocks. Specifically, it responds positively and significantly to a shock in LGDP only during the first period, with a response value of **(**0.8194**)** and a standard deviation of **(**0.3628**),** reflecting a short-term effect running from economic growth toward LEC. However, no statistically significant responses are observed to shocks in LEP and LEI1. In addition,

LEC records a strong and positive response to its own shock during the first period, reaching (1.9524) with a standard deviation of (0.2403)**,** before gradually declining and becoming statistically insignificant in subsequent periods.

Overall, the impulse response analysis indicates that the causal relationship between renewable energy and economic growth is characterized by weak and short-term effects. Significant responses are mainly concentrated in the endogenous shocks of each variable during the first period, after which their effects gradually dissipate. The findings also reveal the presence of a short-term unidirectional causal effect running from economic growth toward some renewable energy variables, while no significant causal effects are detected in the opposite direction.

5.2 Variance Decomposition Analysis

Table 5. Results of the Forecast Error Variance Decomposition Analysis

Variables	Variables' Contributions to the Forecast Error Variance	Period 1	Period 2	Period3	Period4	Period5
LGDP	LGDP	%100	%91,48	%91,18	%91,01	%91,01
LGDP	LEP	0,00	%0,69	%0,72	%0,73	0,73
LGDP	LEI1	0,00	%5,29	%5,25	%5,33	%5,33
LGDP	LEC	0,00	%2,54	%2,85	%2,94	%2,94
LEP	LGDP	%3,45	%5,82	%5,62	%5,61	%5,61
LEP	LEP	%96,55	%92,33	%90,48	%90,06	%89,89
LEP	LEI1	0,00	%0,29	%2,22	%2,64	%2,82
LEP	LEC	0,00	%1,56	%1,68	%1,67	%1,68
LEI1	LGDP	%0,26	%0,21	%0,21	%0,21	%0,21
LEI1	LEP	%5,73	%5,91	%5,86	%5,85	%5,85
LEI1	LEI1	%94,01	%90,93	%91,01	%91	%91
LEI1	LEC	0,00	%2,94	%2,91	%2,94	%2,94
LEC	LGDP	%14,35	%13,96	%13,98	%13,98	%13,98
LEC	LEP	%4,17	%4,33	%4,33	%4,32	%4,32
LEC	LEI1	0,00	%2,31	%2,35	%2,38	%2,38
LEC	LEC	%81,47	%79,39	%79,34	%79,32	%79,32

Source: Prepared by the author based on EViews output

Variance decomposition analysis is one of the principal analytical tools used in VAR models to determine the extent to which each variable contributes to explaining the forecast error variance of a given variable over time. Table (5) presents the forecast error variance decomposition results for the study variables (LGDP, LEP, LEI1, and LEC) over a forecast horizon ranging from periods 1 to 10.

Variance Decomposition Analysis of LGDP**:** During the first period**,** LGDP explained 100% of its own forecast error variance, indicating that economic growth was entirely driven by its own shocks in the short run, with no contribution from the remaining variables. In the second period, the contribution of LGDP declined to approximately 91.48%**,** while the other variables began to contribute, with LEI1 accounting for 5.29%**,**

LEC for 2.54%, and LEP for **0.69%**. During the third and fourth periods, the results remained relatively stable, with LGDP contributing approximately 91%, while the contributions of LEI1, LEC, and LEP stabilized at around 5.3%, 2.9%, and less than 1%, respectively. From the fifth through the tenth period, the decomposition results became virtually stable.

Variance Decomposition Analysis of LEP: In the first period, LEP explained approximately 96.5% of its own forecast error variance, while LGDP contributed about 3.45%, with no contribution from the remaining variables. In the second period, the own contribution of LEP declined to approximately 92.33%, whereas the contribution of LGDP increased to 5.82%. Contributions from LEI1 and LEC also emerged, accounting for approximately 0.29% and 1.56%, respectively. During the third and fourth periods, the results gradually stabilized, with LEP contributing between 90.48% and 90.06%, while the contributions of LGDP, LEI1, and LEC reached approximately 5.62%, 2.65%, and 1.67%, respectively. The decomposition remained almost unchanged from the fifth to the tenth period.

Variance Decomposition Analysis of LEI1: In the first period, LEI1 explained approximately 94.01% of its own forecast error variance, while LEP contributed 5.73% and LGDP contributed 0.26%, with virtually no contribution from LEC. In the second period, the own contribution of LEI1 declined to approximately 90.93%, whereas the contributions of LEP and LEC increased to 5.91% and 2.94%, respectively, while the contribution of LGDP remained weak at approximately 0.21%. During the third and fourth periods, the results were relatively stable, with LEI1 explaining around 91% of its forecast error variance, whereas the influence of LGDP remained negligible. From the fifth to the tenth period, the decomposition results became nearly constant.

Variance Decomposition Analysis of LEC: In the first period, LEC explained approximately 81.48% of its own forecast error variance, while LGDP and LEP contributed 14.35% and 4.17%, respectively, whereas the contribution of LEI1 was almost negligible. In the second period, the own contribution of LEC decreased to approximately 79.39%, while the contribution of LEI1 increased to approximately 2.31%. Meanwhile, the contributions of LGDP and LEP remained relatively stable at approximately 13.97% and 4.33%, respectively. During the third and fourth periods, the results remained broadly stable, with LEC accounting for approximately 79.32% of its forecast error variance, while LGDP, LEP, and LEI1 contributed about 13.98%, 4.33%, and 2.37%, respectively. From the fifth through the tenth period, the variance decomposition results remained virtually unchanged.

Overall, the forecast error variance decomposition results indicate that most of the variables are predominantly explained by their own shocks in the short run, highlighting the dominant role of internal dynamics in determining their fluctuations. The findings

further provide evidence of a causal relationship between economic growth and renewable energy in Algeria.

5.3 Granger Causality Analysis

Table 6. Granger Causality Test Results

Variables	Causal Variable	Prob	Variable	Causal Variable	Prob
GDP	EP	0204, 0	EC	GDP	0,0577
GDP	EC	0,1107	EC	EP	0,5505
GDP	EI	0,1631	EC	EI	0,4454
GDP	EP, EC, EI	0,0410	EC	GDP, EP, EI	0,2359
EP	GDP	0,5177	EI	GDP	0,0423
EP	EI	0,9264	EI	EP	0,3670
EP	EC	0,1493	EI	EC	0,4089
EP	GDP, EI, EC	0,0044	EI	GDP, EP, EC	0,0289

Source: Prepared by the author based on EViews output

The results indicate the existence of a unidirectional Granger causal relationship running from renewable energy production (EP) to gross domestic product (GDP**)**, as the associated probability value **(**Prob = 0.0204) is below the 5% significance level. Accordingly, the null hypothesis is rejected, confirming that EP Granger-causes GDP. In contrast, no causal relationship is found from GDP to EP, since the corresponding probability value (0.5177) exceeds the 5% significance threshold; therefore, the null hypothesis cannot be rejected.

The findings also reveal no direct causal relationship between renewable energy consumption (EC) and gross domestic product (GDP) in either direction. The corresponding probability values are 0.1107 and 0.0577, respectively, both of which are greater than the 5% significance level**.**

With regard to investment in renewable energy (EI**)**, the results indicate the presence of a unidirectional causal relationship from EI to GDP, as the probability value (0.0423) is below the 5% significance level**.** Conversely, no causal relationship is found from GDP to EI, since the corresponding probability value (0.1631) exceeds the significance threshold.

Regarding the relationships among the renewable energy variables themselves, the results show no statistically significant causal relationships between EP and EC, EP and EI, or EC and EI, as all corresponding probability values exceed the 5% significance level, indicating the absence of bilateral Granger causality among these variables over the study period.

Furthermore, the joint causality test reveals the existence of statistically significant joint causal effects of the explanatory variables on certain endogenous variables. Specifically, the variables (EP, EC, and EI) jointly exert a significant causal effect on GDP at the 5% significance level **(**Prob = 0.0410**).** Likewise, the variables (GDP, EI, and EC) jointly Granger-cause EP **(**Prob = 0.0044**),** while (GDP, EP, and EC) jointly Granger-cause EI **(**Prob = 0.0289). In contrast, no significant joint causal effect is detected from (GDP, EP, and EI**)** to EC, as the corresponding probability value **(**0.2359**)** exceeds the 5% significance level.

6. CONCLUSION

This study examined the dynamic causal relationship between renewable energy production and economic growth in Algeria over the period 1990–2025 through both descriptive and econometric analyses of the study variables.

The findings indicate that interest in renewable energy has increased progressively, particularly in recent years, with solar energy emerging as the most important renewable energy source due to Algeria's abundant natural potential. In contrast, the contributions of wind and hydropower have remained relatively limited. The study also examined energy imports and their role in meeting domestic energy demand.

To investigate the dynamic relationship among the variables, a Vector Autoregression (VAR) model was employed. Following stationarity testing, the results confirmed that the time series became stationary after applying the appropriate differencing procedures. The optimal lag length was then determined, and the VAR model was estimated after verifying its statistical adequacy through diagnostic tests, residual analysis, and stability tests.

Furthermore, the Impulse Response Function (IRF) analysis revealed the existence of dynamic interactions between renewable energy variables and economic growth with varying degrees of influence. The Forecast Error Variance Decomposition (FEVD) analysis showed that a substantial proportion of the fluctuations in the variables is explained by their own shocks, while also indicating the presence of interactions between economic growth and renewable energy variables. In addition, the Granger causality test identified a unidirectional causal relationship between the variables.

Overall, the findings suggest that the development of the renewable energy sector constitutes an important driver of economic growth and a key pillar for achieving sustainable economic diversification in Algeria, particularly in light of the country's ongoing energy transition strategy and efforts to reduce dependence on conventional hydrocarbon resources.

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