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THE IMPACT OF ENERGY CONSUMPTION ON ECONOMIC GROWTH IN ALGERIA (1983-2022)

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Abstract

This analytical and econometrical study aims to shed light on the impact of energy consumption on economic growth in Algeria, by using the Algerian data for each G.D.P. as an indicator of real economic growth, on the one hand, and the per capita energy consumption, on the other. We try to understand the evolution of G.D.P. This is to determine the extent of intervention in energy consumption to increase output from 1983 to 2022. Finally, applying econometric techniques starts with the Augmented Dickey-Fuller (A.D.F.) test for stationary, then the Johansen-Juselius cointegration and Granger causality test based on VECM. This paper's significant findings consist of a long-run relationship between G.D.P. and E.C. and a unidirectional causality relationship from E.C. to G.D.P. in both the short and long run; furthermore, in the long run, energy consumption positively influences economic growth in Algeria.

Keywords: *energy consumption; economic growth; causality; co-integration; Algeria.*
JEL Codes: C41; C44; C62; O13.

Introduction

Energy has played and continues to play a significant role in economic development and the well-being of individuals and social groups worldwide. At the same time, access to energy is a subject of increasing concern to the international community since it is essential to the completion of any production process and, therefore, to a country's economic and social development. This means that economic growth simultaneously leads to growth in energy needs. Modern societies use more and more energy for industry, services, homes, and transport.

Furthermore, the direction of the relationship between energy consumption and economic growth remains a subject of debate; some research highlights the impact of energy consumption on economic growth, while another, on the contrary, highlights the

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impact of financial development on the level of energy consumption. Regardless, a link between the two phenomena remains established. In our case, we propose to study this link (in the case of Algeria) without priori indicating the direction of the link. In other words, we are interested in verifying whether there is a link between energy consumption and economic growth in Algeria. Hence, the central question of our work is:

Is there a causal link between energy consumption and economic growth in Algeria?

To answer the question, we formulated the following hypotheses:

- **Hypothesis 1**: Algeria has a unidirectional relationship between energy consumption and economic growth.
- **Hypothesis 2**: A bidirectional relationship exists between energy consumption and economic growth in Algeria.
- **Hypothesis 3**: There is no causal relationship between energy consumption and economic growth in Algeria.

To verify these hypotheses and carry out our work, we adopted a research methodology with a double methodological approach: an exploratory approach to the literature (initially) to identify the theoretical and empirical relationship between energy consumption and economic growth, to identify the variables and measures used to study this relationship and to highlight the evolution and trend of the two phenomena in the case of Algeria. A verification process (in a second step) consists of verifying (in the Algerian context) the existence or not of a relationship between the level of energy consumption and economic growth, i.e. to confirm or refute our hypotheses stated above. This second approach is based on statistical modelling.

Definitions of energy

The ability to work or produce heat is the general definition of energy, according to Subhes C. Bhattacharyya. Typically, heat is produced by burning a fuel, which is a material with intrinsic energy that produces heat when burned. Other methods of producing heat include absorbing solar radiation or heat from rocks underneath the earth's surface. (Subhes C., 2011).

Comparably, the ability (or potential) to perform work (referred to as potential energy, as in water held in a dam) or its manifestation in terms of conversion into motive power (referred to as kinetic energy, as in the case of wind or tidal wave) can be represented by the capacity to do work. Since energy is not always seen as it is, it is difficult to define the concept. In other words, systems require energy in order to operate ; that is, they need effort in order to produce an effect (Başkan Takaoğlu, 2024).

Energy typology

Subhas C. Bhattacharyya confirms that energy can be obtained from various sources; it is customary to classify them under different categories as given below:

Primary energy is used to designate a source of energy extracted from a stock of natural resources or captured from a resource flow that has not undergone any transformation or conversion other than separation and cleaning (A.I.E. 2004). Examples include coal, crude oil, natural gas, solar energy, and nuclear energy.

Secondary energy is all the power obtained by transforming or converting a primary energy. Thus, petroleum products or electricity are secondary energies because they require refining or electrical generators to produce them. Electricity and heat can be obtained as primary and secondary energies.

Renewable and non-renewable energy

- Renewable energy: energy is said to be renewable from a permanently renewed natural source, as opposed to non-renewable energy, whose stocks are depleting (Zohuri, Mossavar-Rahmani, & Behgounia, 2022).
- Nicknamed "clean energy" or "green energy", their exploitation generates very little waste and polluting emissions, but their energy power is much lower than that of non-renewable energies.
- **Non-renewable energy**: these are primary energies that cannot be reconstituted on a human time scale after their use. Oil, natural gas and coal are non-renewable energies (Awodumi & Adewuyi, 2020).
- Fossil fuels, which include coal, oil, and gas, and their origins in living, plant, or animal forms, contain carbon, the combustion of which provides energy and generates carbon dioxide. The amount of carbon in fossil energy is not a tiny proportion existing on earth.

Measures of economic growth

- G.D.P., or Gross Domestic Product, measures the wealth created by a country in a year; that is, it indicates the value of a country's production of goods and services in a year (Biljana , 2023).
- G.D.P. is an aggregate that adds up the wealth created in the country by its productive agents. Thus, a company produces wealth at the microeconomic level, and G.D.P. measures the wealth created at the macroeconomic level by the entire country. Measuring growth through G.D.P. across countries allows for international and historical comparisons. However, G.D.P. has enormous

drawbacks that many economists denounce; this is why some suggest using other aggregates. It is measured by adding market G.D.P. and non-market G.D.P.

- Market G.D.P. covers all market production of companies established in a territory and the wealth created by their productive activity. Market production is production sold at a price covering at least the cost of production. It is, therefore, a production carried out by a production organization with a profit motive: financial or non-financial companies or companies.

On the other hand, endogenous growth theories consider growth as an economic phenomenon. Growth results from investments made by agents motivated by gain. The economy's growth rate is determined by the behaviour of agents and by macroeconomic variables. These different ways of presenting endogenous growth underline the new models' break with the neoclassical growth theory. The renewal of growth theories is based on the achievements of industrial economics, as was the case at the beginning of the 1980s with the renewal of international trade theories. It, in turn, sheds new light on the relationships between growth theory and cycle theory, or the problems of development, the main characteristics of endogenous growth: the presence of increasing returns to scale, the forms of competition which allow a decentralized balance, the sources of growth ((Ralle, 2003).

The Impact of Energy Consumption on Economic Growth.

The increase in energy consumption is the effect of economic growth. Therefore, there is a double correlation between economic growth and energy consumption: a correlation over time (energy-consumed increases in parallel with production measured by G.D.P.) and a correlation in space (the most developed countries are also those with the highest energy consumption) (Warsame, Alasow, & Salad, 2024). According to an American study, the main obstacle to economic growth lies in the quantity of available energy (Honoré, 2014).

A study on the links between economic growth and the overall quantity of available energy, published in the journal "Biosciences", establishes a strong correlation between these two data globally and within a country (Sodik , et al., 2023). Given the importance of energy in the economy, countries with abundant energy resources are more privileged than other countries. They can be considered wealthy if they are exploited precisely and economically (Liuyi , Rui , & Xinran , 2022).

In developed countries, economic growth is sensitive to any variation in energy consumption. This could be attributed to the nature of the financial structure, where the industrial fabric is entirely developed and consumes too much energy (Nicholas M, 2023). Since these countries do not have significant reserves, satisfying this growing demand is accompanied by foreign currency outflows to support energy supply expenses. Hence, they are called upon to follow an energy-saving policy that is much more effective. For this, several studies have been carried out in these countries (Oluyomi A, Afolabi , Martha , & Adekunle , 2020).

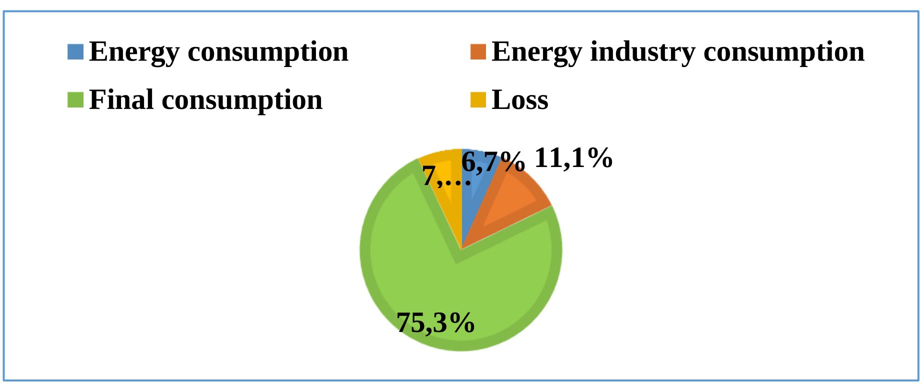
Evolution of national energy consumption by aggregates 1980-2019

Overall energy consumption (including losses) is the sum of final consumption, non-energy consumption and that of energy industries, reaching 66902 KTEP (Ministry of Energy and Mines, National Energy Balance 2019).

According to the national energy balance for the year 2019, national energy consumption is taken into four groups, namely:

- Non-energy consumption (C.N.E.): indicates the quantities consumed as raw materials in the petrochemical and other industries.
- Consumption of energy industries (C.I.E.) concerns transformation units, transport infrastructures, and all energy products consumed in energy-producing industries.
- Final consumption (C.F.) concerns all energy products consumed by end users (industry, household, etc.).
- Overall consumption (C.G.): The three previous aggregates and losses during transport and distribution.

Figure no. 1 Distribution of national energy consumption by aggregates for the year 2019



Source: Ministry of Energy and Mines, National Energy Balances “2022”

The structure of national energy consumption remains dominated by the "final consumption" aggregate throughout 1980-2022 (according to the national energy balances of the Ministry of Energy and Mines). It reached 75.3% in 2022, followed by energy industry consumption (11.1%), then losses at (7%), and finally non-energy consumption at (6.7%). We can illustrate the distribution of global energy consumption by aggregates for 2022 in (Figure 1).

Final consumption represents 75.3% of overall consumption, and it is essential and becomes a critical element that defines an indicator of driving forces and shows trends in final energy consumption. It aims to consider any initiative to reduce or rationalise energy consumption and improve energy efficiency for the various end users.

Evolution of final energy consumption by form and sector:

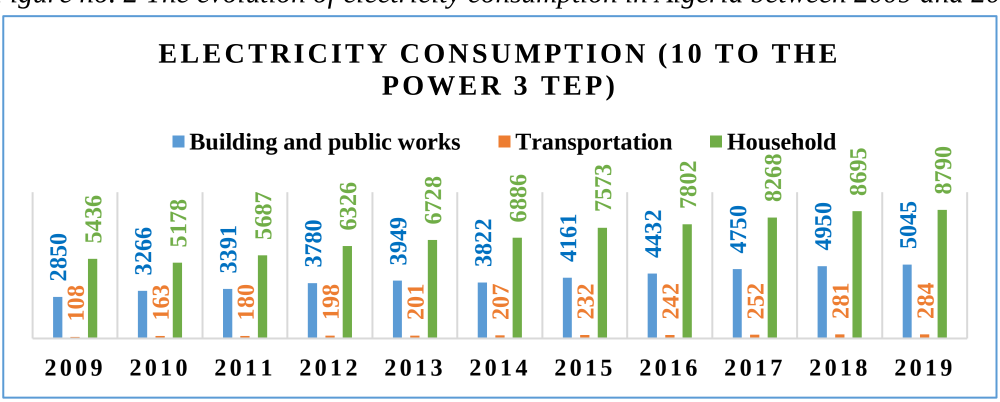
According to the Ministry of Energy and Mines, the 2019 national energy balance shows that final consumption is identified in three sectors. On the one hand, industry, construction and public works, then the transport sector and finally, the household and another consumer sector. Furthermore, Algeria's primary forms of energy are electricity, natural gas, petroleum products and finally liquefied (L.P.G.).

Changes in electricity consumption by sector of activity between 1980-2022

Algeria is making enormous efforts to provide energy due to the growing need of citizens for electricity, and access is becoming a challenge for social and economic development.

For electricity, the installed capacity is 18,000MW until the end of 2022, and the coverage of the country by the electricity network is at a comfortable rate of 98% (according to the Ministry of Energy and Mines, the national energy balance of the year 2019, Algeria press service). And according to the public operator SONELGAZ, the total number of subscribers has reached nearly 10 million electricity customers.

Figure no. 2 The evolution of electricity consumption in Algeria between 2009 and 2019



Source: Ministry of Energy and Mines, National energy balances "2009 -2019"

According to the figure above (Figure No. 2), electricity consumption for the three sectors increased constantly between 2009 and 2018.

For the household sector and other consumers, the evolution of electrical energy consumption between 2009 and 2018 saw an increase from (5,436 KTEP) in 2009 to (8,790 KTEP) in 2019, with an increase of 161.69%.

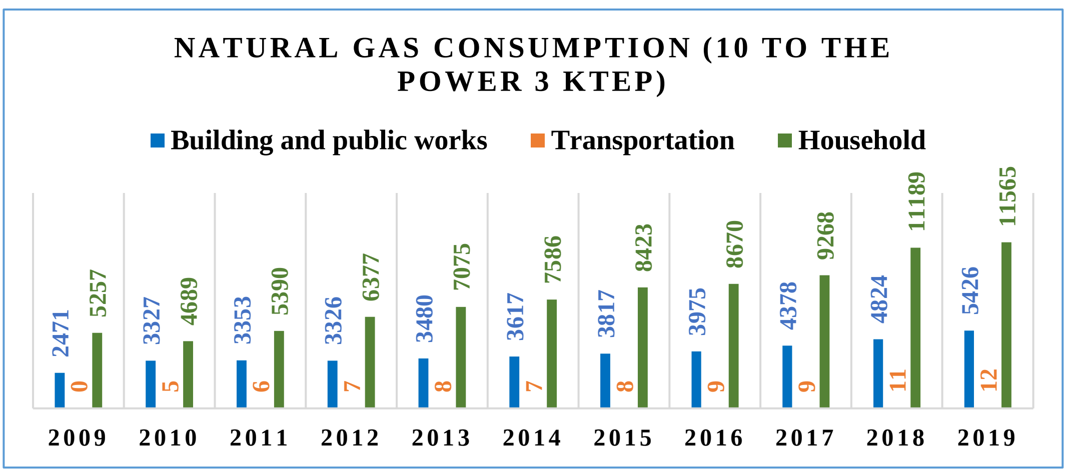
Meanwhile, for the industry, building and public works (I.BTP) sector, there was a perpetual increase of (177.01%) from 2009 to 2019, from (2,850 KTEP) to 5,045 KTEP) in 2019.

Concerning the transport sector, the evolution of electrical energy consumption increased by 262.96% from 2009 to 2019, with growth from 0.108 KTEE in 2009 to 0.284 KTOE in 2019.

Evolution of natural gas consumption by sector of activity (C.G.N.)

Domestic consumption of natural gas began with the discovery of the HASSI R'MEL deposit (its commissioning in 1961), with an annual rate of approximately 140 million m3. (Khelifa, 2023). The public operator SONELGAZ announced that the total number of subscribers had passed 6 million customers for this type of energy (gas).

Figure no. 3 Natural gas consumption by sector of activity in Algeria between 2009-2019



Source: National energy balances of the Ministry of Energy and Mines "2009-2019"

According to the Ministry of Energy and Mines' national energy balances, the final consumption of natural gas during the period from 2009 to 2019 was constantly growing.

For the household sector and other consumers, the evolution of natural gas consumption notes a perpetual increase during 2009-2019, going from 5257 KTEP in 2009 to 11565 in 2019 with a growth of 45.45%.

Likewise, the consumption of natural gas in the industry, building and public works sector recorded growth of 45.56% during 2009 - 2019, compared to 2471 KTEP in 2009 and reached 5426 KTEP in 2018.

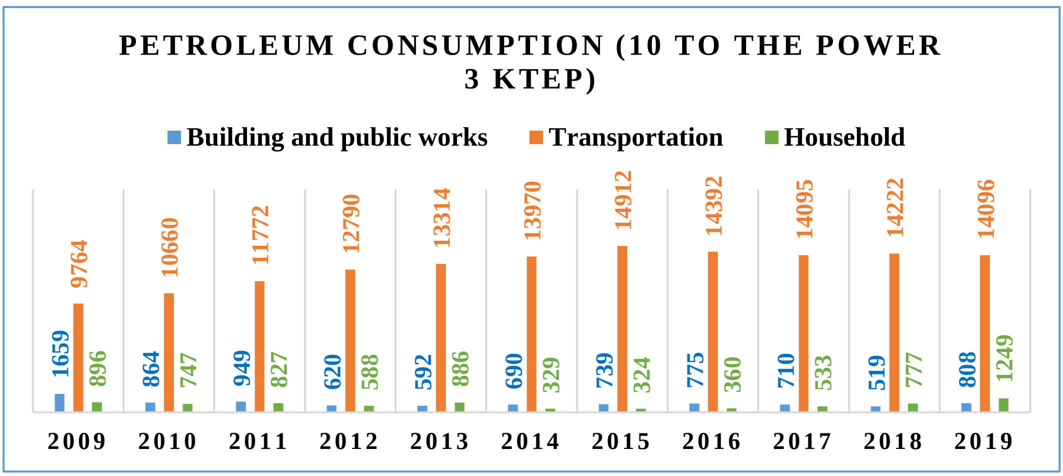
For the transport sector, natural gas consumption will start in 2010 with 0.005 KTEP to reach 0.012 KTEP in 2018 with an increase of 41.66%.

Evolution of consumption of petroleum products by sector of activity during 2009-2019 (C.P.P):

Algeria has markets for fuels and petroleum-derived products (gasoline, diesel, etc.), mainly owned by the public company NAFTAL, a subsidiary of the SONATRACH group.

According to (Figure No. 4) below, the consumption of petroleum products from 2009 to 2019 experienced a perpetual increase.

Figure no. 4 The evolution of the consumption of petroleum products by sector of activity



Source: Ministry of Energy and Mines, National energy balances "2009 – 2019"

For the industry, buildings and public works sector, the change in consumption of petroleum products for the period 2009-2018 decreased from 1.659 KTEP in 2009 to 0.808 KTEP in 2019, with a drop of 48.70%.

Concerning the transport sector, the evolution of consumption is not stable, with irregular increases or decreases; it experienced a rise of 9,764 KTEP in 2009 and reached 14,912 KTEP in 2015 and notes a reduction in 14,392KTOE in 2016, came 14,096 KTOE in 2019, while it recorded over the period "2009 -2019" a rate of 62.29%. For the household sector, the evolution of consumption is not stable with irregular increases or decreases.

Algerian Energy Policy

We will present security and the choices of an energy policy, then the state of play of renewable energies, energy efficiency and the energy transition in Algeria. Finally, the link between hydrocarbon energy and economic growth in Algeria.

Security and choice of an energy policy

Algeria has enormous potential for renewable and non-renewable energy resources, which it aspires to develop. It specifies the foundations and directions of its energy policy to develop the exploitation of different energy resources. The various sectoral consultation processes have led to the development of a global energy policy framework in Algeria, which shows the role of this sector in achieving the social and economic development of the country, while taking into account the challenges posed by the preservation of the environment and the trend towards investment in alternative energies to achieve energy efficiency (Mines, 2014).

The Algerian government has framed energy policy with a set of laws and legislation in line with the different orientations specified in its energy strategy to develop and regulate them, and they are as follows (Ghezloun, Oucher, & Chergui, 2012):

- Specify and set the conditions of the national energy management policy, which includes all measures and activities applied to rationalize the use of renewable energies by the environmental system.
- Achieve sustainable development and preserve non-renewable energy resources while meeting diverse national energy needs and improving productivity.
- Enhance oil and gas production by creating more industrial-added value and employment.
- The use of particular energy efficiency measures linked to devices that use electricity, gas and petroleum products with the realization of their thermal insulation process (Transition énergétique en Algérie, 2020).
- Promote and develop renewable energies to gradually reduce the national consumption of petroleum products, ensure the supply of the entire national territory with electricity and gas, and guarantee the best conditions of safety and quality.

National Energy Transition Program 2020 (PNTE)

The energy transition is essential in the government's action plan, which focuses on "the triptych of economic renewal based on food security, the energy transition and the digital economy". The energy transition program aims, in addition to the diversification of energy sources through the development of renewable energies, to promote energy efficiency as a complementary action of great importance (Dib, 2012). The country thus aims to gradually free itself from dependence on conventional resources and initiate a dynamic for the emergence of green and sustainable energy, available locally and in abundance, such as solar power. The approach is based on the following considerations:

- The preservation of fossil resources and their valorization;
- Sustainable development and environmental protection;
- Controlling the costs of creating renewable energy installations.

Regarding the development of renewable energies

A program for developing renewable energies with a capacity of 16,000 MW by 2035, exclusively based on photovoltaic solar power, has been submitted as one of the centrepieces of the energy transition in Algeria, according to the Ministry of Energy. Thus, 15,000 MWp are intended to be produced exclusively by solar power plants connected to the national electricity network, of which a first tranche of 4,000 MWp is to be produced by 2024 while the remaining 1,000 MWp are to be deployed autonomously at horizon 2030 (Bouznit, Pablo-Romero, & Sánchez-Braza, 2020).

On another level, hybridising electricity production based on conventional resources (diesel and gas) in the country's south with photovoltaic solar power was also presented as a priority for developing off-grid renewable energies (autonomous production).

Under the energy efficiency policy:

The firm measures that the government plans to implement in terms of energy efficiency are aimed at drastically reducing waste. It was recommended to encourage this trend, the implementation of which, at the level of the different sectors of activity, will be focused on the following measures ((MEM), Mars 2011):

- The establishment of a national program for the conversion of tourist vehicles to LPGc and the development of C.N.G. for public transport vehicles;
- Equipping the public lighting network and the various buildings housing national administrative services with low-consumption devices;
- The establishment of a regulatory framework prohibiting the import and production of energy-consuming equipment.

The Evolution Between G.D.P., Hydrocarbon and HH GDP in Algeria

The energy sector occupies a special place in the economy because it constitutes an essential source of wealth on which the Algerian economy depends mainly on the hydrocarbon sector, which contributes significantly to economic growth.

The increase in international oil and gas prices allows Algeria to enjoy a comfortable financial situation. Therefore, the Algerian economy is rentier, and economic growth is highly dependent on oil and gas prices. Today, this dependence is seen as a weakness because it remains dependent on international oil prices. In other words, the entire Algerian economy is subject to fluctuations in the oil and gas markets, as shown in the table and figures below.

Table no. 1 - Comparative evolution between G.D.P, hydrocarbon and HH GDP in Algeria

	PIB	PIB H	PIB H%	PIB HH	PIB HH %
2011	9968	3109,1	31,19	6858,9	68,81
2012	11991,6	4180,4	34,86	7811,2	65,14
2013	14588,5	5242,5	35,94	9434	64,68
2014	16208,7	5536,4	34,16	10672,3	85,84
2015	16643,8	4698	38,23	11675,8	70,15
2016	17205,1	4657,8	27,07	12547,3	72,93
2017	16712,7	3134,2	18,75	13578,4	81,25
2018	17504,6	3025,6	17,28	14489	82,77
2019	18575,8	3699,7	19,70	14876,1	80,10
2020	20259,9	4457,8	22	15711,3	75,55
2021	20284	3910,1	19,28	16374	80,72

Source: Based on data from the National Statistics Office (O.N.S.)

To eliminate the effect of the added value created by other sectors without that of hydrocarbons, we have broken down the G.D.P. into two parts: hydrocarbon G.D.P. (H G.D.P.) and non-hydrocarbon G.D.P. (HH GDP) with GDP=H GDP+HH GDP

G.D.P. H: The added value created by the hydrocarbon sector depends on the quantity of oil exported and the prices set by the world oil market.

GDP HH: This is the added value created by the non-hydrocarbon sector (agriculture, investments, services, industries, etc.).

The link between hydrocarbon energy and economic growth in Algeria

The relationship between energy consumption and economic growth is very close. Energy is an essential element of the economy and a significant factor of production. The energy sector in Algeria plays a central role in the country's economic development, and its mission is to ensure that energy needs are covered thanks to revenues from the exports of these hydrocarbons. Hydrocarbons alone represent 60 % of the budget and 98% of export revenues (Siouane, 2021).

Hydrocarbon production generated substantial revenues for the country between 1995 and 1998, reaching 60 billion DA of the state budget, or 18 to 20% of G.D.P. (Mondiale, 2008).

Two thousand two hydrocarbon exports totalled $18 billion, while imports linked to sector operations stood at approximately $2 billion. However, the extreme dependence of the State on these resources for four decades has determined three negative consequences, which structurally affect the entire economy. The first consequence is that the creation of industrial jobs could be higher due to low labour intensity in hydrocarbon production. The second consequence is that fluctuations in oil prices lead to significant volatility in the balance of payments, budgetary revenues, and the money supply, which is a considerable source of fragility for the economy as a whole. The third consequence is the rent, resulting from this hyper-profitable sector; it has allowed Algeria to have financial resources far superior to those of its neighbours, and this capacity continues to offer the country the financial means for rapid economic growth (Cherfi , 2010).

Econometric Study of the Impact of Energy Consumption on Economic Growth: Data on Algeria (1983-2022)

To know the relationship between the variables of the phenomenon studied, it is necessary to determine the dependent variable and the different external variables explaining the standard phenomenon studied.

Dependent variable: The economic growth rate is expressed in current prices of the local currency, and we call it (G.D.P.)

Variables explained: Certain variables were identified to explain the standard phenomenon, the statistical data of which was available from the Economic Development Indicators and downloaded directly from the World Bank website ranging from 1983 to 2017, and updated until April 2022:

- Energy consumption (in KTEP per barrel), which we designate by the symbol (E.C.).
- Consumption of renewable energy (current prices in KTEP currency: thousand tonnes of oil equivalent), symbolized by the symbol (CERN).

Through this study, we also try to rely on the logarithmic model, which is considered one of the best models to address the problem of linearity between the variables of the study and the problem of variance. We can use the logarithmic model to calculate the elasticities linked to the variables of the time series studied.

$$GDP_t = C_0 + C_1 * EC_t + C_2 * CERN_t + \varepsilon_t$$

Knowing that:

C_0, C_1, and C_2: They express the model parameters and estimation using the least squares method, which is considered the best method for estimating the capabilities of standard models.

ε: It expresses the value of the random error resulting from measurement errors or from the calculation error of the standard model by neglecting certain external variables that we cannot sometimes measure, mainly qualitative variables such as adult governance, business climate, democracy and other variables that can explain the estimated model.

Estimation of the model equation using Eviews. 12:

Table no. 2 - Estimation of the model equation

Dependent Variable: **G.D.P.**				
Method: Least Squares				
Date: 06/09/21 Time: 09:19				
Sample: 1983 2022				
Included observations: 39				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5,75-E+10	1,65E+10	3,478854-	0,0013
EC	,4089641	359254,4	11,38369	0,0000
CERN	1,43E+11	6,74E+10	2,119905	0,0410
R-squared	0.806309	Mean dependent var	9.70E+10	
Adjusted R-squared	0.795548	S.D. dependent var	5.91E+10	
S.E. of regression	2.67E+10	Akaike info criterion	50.93089	
Sum squared resid	2.58E+22	Schwarz criterion	51.05885	
Log-likelihood	990.1523	Hannan-Quinn criteria.	50.97680	
F-statistic	74.93131	Durbin-Watson stat	0.479684	
Prob(F-statistic)	0.000000			

Source: Established by the student using Eviews software.12

According to the table above and the results of the estimation of the linear model, we can write the regression equation in the following form;

$$\boldsymbol{GDP = -57453074543.3 + 4089640.89815 * EC + 142970813548 * CERN}$$

Study the quality of the linear model

First - the economic study

In the previous table relating to the outputs of the Eviews .12 program, we note that:

Regarding the coefficient of energy consumption (Ec), its sign is positive, i.e. there is a direct relationship between this variable and the level of economic growth, which is consistent with economic theory, i.e. an increase in the level of consumption would increase economic activity, according to the estimated equation, an increase in energy consumption of one unit would contribute to the level high economic growth 4089641 unit.

Concerning the renewable energy consumption coefficient (CERN), we note through the program outputs that its sign is positive, i.e. there is a positive relationship between this variable and growth rates, which is consistent with economic theory because increasing the volume of renewable energy consumption by one unit would contribute to the increase in the volume of G.D.P. by 1.43E+11

Second: the statistical study

Significant study of the model

We test the overall significance of the estimated model using the coefficient of determination as well as the Fisher test through the following two hypotheses:

H0: The model is not appropriate (i.e. the external variables do not explain the phenomenon studied)

H1: The model is appropriate (i.e. the external variables explain the phenomenon studied)

First, we extract the tabular value corresponding to the Fisher statistic and compare it with the calculated one. The number of observations is 39 views.

Tabular value: $F_{(n-k-1)} = F_{(39-2-1)} = F_{36}$

Table no. 3 - Fisher test results

	Au niveau de 1%	**Au niveau de 5%**	**prob**
F_{tab}	5,25	3,26	**0,0000**
F_{cal}	74,93131		

Source: Established by the student using Eviews software.12

The table makes it evident that, at the 1% and 5% levels, the value of the computed Fisher statistic is higher than the tabular Fisher's, or that ($F_{cal} > F_{tab}$). As a result, we support the alternative hypothesis—that is, that the model is appropriate and that the examined external variables help to explain economic growth rates—and reject the null hypothesis.

The determination rate ($R^2 = 0.80$), which is close to one, and this means that the independent variables explain 80% of the dependent variable (G.D.P.) and keep 20% for the other variables, which can explain the model except that it is Most of the time, these are qualitative variables that cannot be measured.

The meaning of parameter testing

The following hypotheses about the estimated parameters are tested in order to determine the relevance of the estimated model parameters and the impact of the interpreted variables on the dependent variable:

$$\boldsymbol{H_0}: C_0 = C_1 = C_2 = 0$$
$$\boldsymbol{H_1}: C_0 \neq C_1 \neq C_2 \neq 0$$

The test (t-stat) results for the estimated model can be illustrated by the following table, in which we explain the calculated values for the estimated parameters and t tabular values, as well as the lowest probability level at a significance level of 5%. The tabular value of a statistic (t-stat) that we extract from a student table has the same meaning and degree of freedom (np); n represents the number of observations, and p represents the number of estimated parameters of the model. It is equal to ($np = 39 - 3 = 36$), and the following table explains it.

Table no. 4 - Parameter testing

	The settings	$T_{Calculated}$	$T_{Tabulated}$	$T_{Tabulated}$	Prob
			At the 1% level	At the 5% level	
Constante	C0	-3,478	-4,219	-3,53	**0,0013**
Ec	C1	11,38	-4,219	-3,53	**0,0000**
CERN	C2	2,119	-4,219	-3,53	**0,0411**

Source: Established by myself using Eviews software.12

In the table above, we note the following:

• Regarding the coefficient of the constant variable (C0), we note that the calculated value is less than the tabular value, that is, $T_{cal} \leq T_{tab}$ at all levels, and with this, we will accept l null hypothesis and reject the alternative hypothesis, that is to say that the constant I.S. significant in the estimated model and with an error probability of 0.0013.

• Regarding the E.C. coefficient (C1), we note that the calculated value of the Student statistic is also lower than the tabular value, which means that the parameter (C1) is significant in the proposed model.

• Regarding the CERN coefficient (C2), we note that the calculated value of the Student statistic is also lower than the tabular value, which means that the parameter (C2) is significant in the proposed model.

Cointegration Model and Error Correction Model

Cointegration analysis determines the actual relationship between the variables in the long term because the time series under study may not be stationary in the short term. Still, they become stationary in the long term, i.e., there is a stable relationship between them, called a cointegration relationship, and it reveals the problem of missing the Stability of the time series. The unit root test should be carried out initially. After proving the Stability and integrity of the time series to the same degree, we use the error correction model in the second stage because the second stage is only implemented if the Stability and integrity of the time series are proven. The same rating is by the Angel-Granger test, and there is another test related to the simultaneous integration model proposed by Johannsen, as it is considered better than the first test, especially when the sample size is small.

Regarding instability and integration of time series of the same order, i.e. there are integrated time series of order (I = 0) and other integrated series of the first order (I = 1). We must not use the two previous tests linked to the joint integration model. Whether for Granger or Johannsen, another test must be carried out in connection with the cointegration test using the Limit Approach (ARDL), which is used in the case of unstable and incomplete time series of the same order, provided that the order of integration does not exceed the first degree (in other words, this test is only used for the degree of integration (I = 0) and (I = 1).

After confirming the Stability of the time series of the study model variables, which are of the same degree, and then verifying that they are integrated synchronously (joint), it becomes clear that, according to one of the tests above, there is an equilibrium relationship in the long run between the dependent variable and the sum of the independent variables. Therefore, we must move on to the representation of the error correction model.

This model is estimated by adding the estimated one-year slowdown residuals into the short-run regression as a single-period slowdown independent variable alongside differences in other non-static variables as follows:

$$dGDP = C_0 + C_1 dEC + C_2 dCERN_t + +E_{t-1} + \varepsilon_t$$

This mathematical form is called an error correction model because it considers the dynamics of the studied time series in the short and long term between the dependent and independent variables that explain the phenomenon studied. The emergence of (Et-1) in the above equation reflects the earlier assumption that the value of economic growth rates in the short run is not equal to its equilibrium value in the long run.

This partially corrects this imbalance in the short term, and here is the limiting coefficient of error correction, which is the parameter of modifying the fundamental values of the economic growth rates towards their equilibrium value from period to period because this parameter measures the percentage of imbalance in the Slowdown period (t-1) that is corrected or modified in period (t).

Study of stationarity of time series using the Dickey-Fuller test (Dickey & Fuller, 1981)

– **Series stationarity test (G.D.P.)**

H_0: the series has a unit root; that is, it is unstable when $T_{tab} < T_{cal}$

H_1: the series does not contain a unit root, i.e. (the chain is stable) $T_{tab} > T_{cal}$

Table no. 5 - Stationarity of the series (GDP) as tested

Series	**At the level**			**At the 1st difference**			**Degree of stationarity**
GDP	**Constant**	**Constant and trend**	**No one**	**Constante**	**Constant and trend**	**No one**	
	-0,65	-1,56	0,698	-5,51	-5,43	-5,39	I = (1)
Prob	0,84	0,78	0,86	0,0000	0,0004	0,000	

Source: Established by the student using Eviews software.12

At the level:

Regarding the constant: the calculated student statistical value is greater than the tabular values at all critical levels (1%, 5%, 10%), and the corresponding probability is greater than the necessary values, it is, i.e. $t_{tab} < t_{cal}$ and therefore we accept the null hypothesis, i.e. the G.D.P. series has a modulus root and thus is not stationary at the level (I = 0).

For the constant and the trend, we note that the calculated Student statistic is greater than the tabular value at all levels, and the corresponding probability is also more significant than the critical values (1%, 5%, 10%), that is to say, ttab< t cal, We, therefore, accept the null hypothesis, that is to say, that the G.D.P. series has a unit root and thus does not stabilize at the level (grade I = 0).

Compared to without the constant and the direction: ttab <t cal, and therefore, we accept the null hypothesis, that is to say, that the G.D.P. series has a unit root and thus does not stabilize at the level (degree I = 0). We test this series in the first teams using the same test, as noted:

At the first difference:

Regarding the constant, we notice that the Student statistic is lower than the tabular value at critical values (1%, 5%, 10%), and the corresponding probability is lower than 1%, 5%, and 10%. Hence, we reject the null hypothesis and accept the alternative hypothesis, i.e. this series contains neither root nor unit and is, therefore, stationary to the first degree (I = 1).

Concerning the constant and the trend, we note that $t_{tab} > t_{cal}$ is at 5% and 10%, and the corresponding probability is lower than all the critical values. Therefore, the series does not contain a unit root, which makes it stationary at the first difference.

Concerning the absence of constant and the trend: We note that the Student statistic is lower than all critical values, and the corresponding probability is lower than 1%, 5%, and 10%, and we, therefore, accept the alternative hypothesis, which is that the series does not contain a unit root, which makes it stationary at the first rank.

Stationarity test of the series (E.C.): We test the same previous hypotheses to determine the degree of Stability of the energy consumption series.

Table no. 6 - Chain stability (EC) according to the ADF test

Series	**At the level**			**At the 1st difference**			**Degree of stationarity**
EC	**Constant**	**Constant and trend**	**No one**	**Constant**	**Constant and trend**	**No one**	
	2,53	0,35	6,78	-5,47	-6,82	-0,67	I = (1)
Prob	1,000	0,99	1,000	0,0001	0,0000	0,41	

Source: Established by the student using Eviews software.12

It is clear from the results of the standard program that this series is not stationary at the level since the statistical values of the calculated student are higher than the table at all critical levels (1%, 5%, 10%), in particular for the first and third model, and the corresponding probability for each of the constants only. In other words, this series is of type D.S. without deviation, and the first difference is the best way to make it stationary.

But when performing the test at the first difference, it was noticed that the series is stationary in the first degree, since the statistical values of a student are significant, since their value was less than the tabular values at all critical values, in addition to the corresponding probability was much lower than these critical values, which makes us reject the null hypothesis We accept the alternative hypothesis that the energy consumption does not contain a root and a unit in both the constant and the trend, or set. Therefore, this series is stationary in the first row.

• Stationarity test of the series (CERN)

We test the Stability of this series through the two previous hypotheses linked to the null hypothesis and the alternative hypothesis; the results are presented in the following table:

Table no. 7 - Stationarity of the series (CERN) according to the A.D.F. test

La série	**At the level**			**At the 1st difference**			**Degree of stationarity Constant**
CERN	**Constant**	**Constant and trend**	**No one**	**Constant**	**Constant and trend**	**No one**	
	-3,46	-4,12	-2,84	-11,15	-3,438	-1,578	I= 1
Prob	0,0146	0,0125	0,0057	0,0000	0,0620	0,1065	

Source: Established by the student using Eviews software.12

It is clear from the results of the estimated program that this series is stationary at the level since the value corresponding to the student's statistic is more significant than all critical values. The probability of errors for this series is greater than the necessary values, which makes the null hypothesis acceptable, meaning that this series contains a unit root. Therefore, it is stationary at the level and stabilizes when the first differences are made in the three models.

Cointegration Test Using the Johansen Method.

This test is considered better than the two-step co-integration test for Angel–Granger (Johansen & Juselius, 1990), (Engle & Granger, 1987), especially when the sample size is small. After our study of the stationarity of the studied time series, which we have found stabilizes in the first degree; we determine the optimal degree of delay using Eviews.12.

According to the known Akaike (Akaike, 1974) and Schwarz (AS) standard norms, the optimal delay period is p = 1, as shown in the table below.

Table no. 8 - Extraction of the degree of delay according to the Akaike and Schwarz standards

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1257,085	NA	5,07e+26	70,00472	70,13668	70,05078
1	**-1143,366**	**202,1669***	**1,51e+24**	**64,18700**	**64,71484***	**64,37123***
2	-1133,473	15,93935	1,46e+24*	64,13737*	65,06109	64,45977
3	-1129,210	6,157157	1,95e+24	64,40056	65,72015	64,86113

Source: Established by the student using Eviews software.12

Most criteria, including Akaike and Schwarz, demonstrate the degree of delay or delay is 1. This is a necessary condition for performing the Johansen test, and the following table highlights the co-integration relationship with its use.

Johansen test

Table no. 9 - Johansen Test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0,490664	37,08976	24,27596	0,0007
At most 1	0,246527	**12,12778**	**12,32090**	**0,0538**
At most 2	0,043731	1,654491	4,129906	0,2329
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0,05 Critical Value**	**Prob.****
None *	0,490664	24,96198	17,79730	0,0035
At most 1	**0,246527**	**10,47329**	**11,22480**	**0,0676**
At most 2	0,043731	1,654491	4,129906	0,2329

Source: Established by ourselves using Eviews software.12

Thanks to the outputs of the software used, it becomes clear that the results of the impact test of the null hypothesis that the number of cointegration vectors is less than or equal to R since the value of the most excellent calculated probability is greater than the tabular value of the first row, i.e. $12{,}12 < 12{,}32$ and hence we reject the null hypothesis. We accept the alternative hypothesis to have a relationship of mutual complementarity over the long term. Therefore, it can be said that there is a typical cointegration relationship between the studied variables, and this is shown by testing the effect in the second row,

where $10{,}47 < 11{,}22$. Therefore, we accept the second null hypothesis that there is only one covariance relationship, i.e. R = 1
Selecting the maximum characteristic value, Max tests the null hypothesis that the number of isometric vectors is R = 1 instead of the alternative hypothesis that it is equal to r +1 (Because $10{,}47 < 11{,}22$).

Error Correction Model (VECM)

After verifying the existence of a Co co-integration relationship between the studied variables, it must push the error correction model because it studies the possibility of the existence of the Co co-integration relationship in the short term, which takes into account the value of the errors slowed down by one period. For reference, the residual series (U) station arises at the level after the test of two unit roots, confirming the existence of a co-relation integration between the estimated variables.

To formulate the error model, which indicates the existence of a short-term equilibrium relationship, we delay the series by the remainder of a period by the following equation: $\boldsymbol{dGDP_t = C_0 + C_1\, dEC_t + C_2 dCERN_t + \gamma_{\,U(-1)}}$

Table no. 10 - Error correction model (VECM)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2,34E+09	3,64E+09	0,643594	0,5242
DEC	686952,3	1944397,	0,353298	0,7260
DCERN	1,43E+10	4,26E+10	0,336600	0,7385
U(-1)	**-0,075847**	0,116808	-0,649327	0,5205
R-squared	0,014281	Mean dependent var		3,08E+09
Adjusted R-squared	-0,072694	S.D. dependent var		1,53E+10
S.E. of regression	1.59E+10	Akaike info criterion		49.91501
Sum squared resid	8.58E+21	Schwarz criterion		50.08738
Log-likelihood	-944.3851	Hannan-Quinn criteria.		49.97634
F-statistic	0.164198	Durbin-Watson stat		1.804736
Prob(F-statistic)	0.919735			

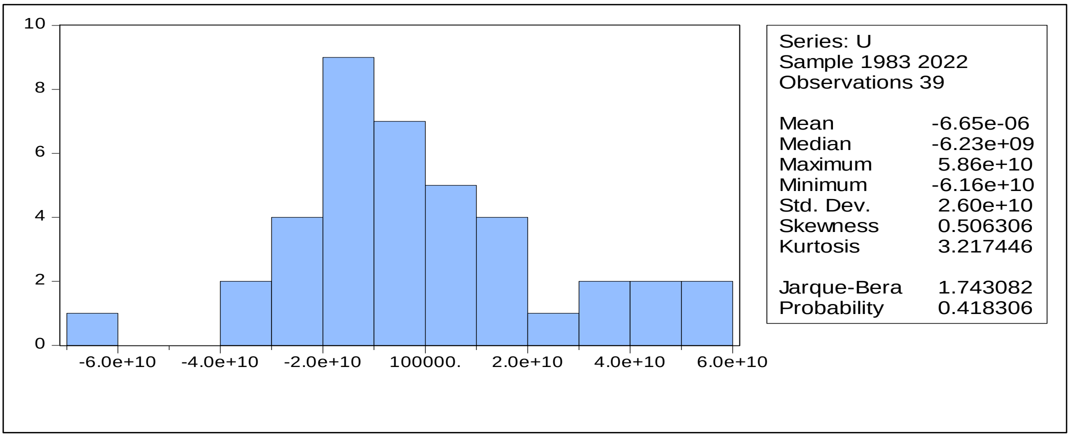
Source: Established by ourselves using Eviews software.12

The table shows that the error term's value is negative and equal to $(-0{,}0758)$, and the negative sign is explained by proving the existence of the long-term equilibrium relationship between the variables studied, as mentioned above. This parameter reflects the speed of adaptation of the model to move from short-term imbalances to long-term equilibrium, where the value of the error correction limit factor indicates that the G.D.P. rate as the dependent variable is adjusted towards its equilibrium value in each period, which is equivalent to 7.58 %, which means that when it deviates from its equilibrium value, the G.D.P. rate in the short period (t-1) equivalent of 7.58% is corrected in period (t). The positive sign for energy and renewable energy consumption is also noted, which is consistent with economic theory.

Some tests on the residual series

A- Test of the normal distribution of the residual series: the figure below shows the form of the normal distribution that the series of residuals takes, with a probability more significant than the critical value, i.e. $0{,}41 > 0{,}05$ which proves that the residual series is naturally distributed

Figure no. 5 Test of the normal distribution



Source: Established by myself using Eviews software.12

Test for heterogeneity of variance

The table below shows the ARCH test for the heterogeneity of variance problem. All probabilities associated with the Fisher statistic and the coefficient of determination are more significant than the critical values, proving the consistency of variance uniformity.

Table no. 11 – ARCH Test

Heteroskedasticity Test: ARCH			
F-statistic	11,73027	Prob. F(1,36)	**0, 3216**
Obs*R-squared	9.338941	Prob. Chi-Square(1)	**0.4322**

Source: Established by myself using Eviews software.12

Conclusion

The most important part of this research work is that I studied the causal relationship between energy consumption and economic growth in Algeria from 1983 to 2022. Starting with the specification of the lag length and the stationarity of the series. Applying the Dickey-Fuller test showed that the first difference series is stationary. Concluding with the application of VECM-based cointegration and Granger causality, it was found that unidirectional causality runs from E.C. to G.D.P. in both the long and short term. Based on the results of this study, the overall recommendation is to prioritize an increase in energy efficiency through technological development and the use of cleaner production resources.

Statistical modelling is considered the most critical part of verifying the existence or not of a relationship between the variables. These two processes were based on applying empirical studies using the Augmented Dickey-Fuller (A.D.F.) test to test stationarity, then Johansen-Juselius cointegration and the Granger causality test based on the VECM test to study the relationship between energy consumption, economic growth in Algeria in 1983 - 2022. Several conclusions were drawn, and they are as follows:

Determination of the degrees of delay: the specification of the degree of delay P is an important practical question. To this end, the optimal shift degrees for the variables are chosen based on the Akaike and Schwarz information criteria. According to this rule, the optimization of the Akaike and Schwarz criteria admits several P*= 1. This is a necessary condition for performing the Johansen test.

Stationarity Test: After determining the degree of delay, the first step is to implement the augmented Dickey-Fuller test. The results indicate that all series are non-stationary levels and are generally D.S. On the other hand, the A.D.F. statistics in the first differentiation suggest that they are stationary.

Johansen cointegration test: After implementing the augmented Dickey-Fuller test, the next step is to check the running relationship between all variables. The cointegration results confirm that energy consumption (E.C.), economic growth (G.D.P.), and renewable energy consumption (CERN) are cointegrated, and there is a cointegration vector (r) in the long term.

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