

The Impact of Energy Consumption on the Environment in Algeria Using the Dynamic ARDL Approach

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Abstract:

This study examines the relationship between energy consumption and environmental degradation, focusing on CO₂ emissions, in Algeria. The authors use the ARDL model to analyze the long-run and short-run relationships between energy consumption, economic growth, oil production, and carbon dioxide emissions from 1980 to 2020.

The results show that energy consumption has a significant positive impact on CO₂ emissions in both the short-run and long-run. GDP per capita also has a positive long-run relationship with emissions, while oil production exhibits a weak negative correlation. The study confirms the existence of the Environmental Kuznets Curve, with GDP per capita squared having an inverse relationship with emissions in the long-run. According to dynamic movement analysis, it's also verified that a shock in energy consumption affects carbon emission in the long-run.

We recommend a range of policy interventions to address Algeria's energy-related environmental challenges, including energy efficiency measures, renewable energy development, sustainable urban planning, and industrial innovation. Strengthening environmental regulations, international cooperation, and financial mechanisms to support green technology are also proposed. The findings highlight the need for Algeria to balance economic growth with environmental sustainability through comprehensive policy reforms.

Keywords: Energy consumption, Environmental degradation, Short-run and Long-run relationship, ARDL model.

JEL Classification: Q50; Q5.

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1. Introduction:

Countries always seek to achieve economic prosperity by raising the level of economic activity through increasing the gross domestic product and seeking scientific and technological progress, but this pursuit of increasing the growth rates of the product requires the widespread and continuous use of energy resources that negatively affect the state of the environment due to polluting carbon emissions. The trend that the world has known in the field of production, especially after the industrial revolution, has led to an increase in carbon emissions and a gradual rise in the temperature of the Earth and the creation of what is known as the phenomenon of global warming and a noticeable and interesting rise in sea levels.

The awareness of the seriousness of this phenomenon has led the countries of the world to work on concluding international agreements and conferences, such as the Earth Summit in 1992 in Brazil, as attempts to limit these environmentally harmful phenomena by reducing carbon emissions and moving towards economic growth that cares for the environment and creating new energy sources that are friendly to the environment.

The North African nation of Algeria is making efforts to increase the pace of its economic development, has in turn witnessed an increase in the phenomenon of environmental pollution as a result of its use of energy sources in most of its production and even service sectors, especially the transportation sector. Algeria's growth depends mainly on the hydrocarbon sector, as this sensitive sector contributes approximately 35% to the gross domestic product and about 95% of the country's exports, and is considered the main financier of the public treasury thanks to oil taxation. Algeria's dependence on the hydrocarbon sector has made its economic growth characterized by a kind of fragility due to the fluctuations that oil prices experience from time to time.

Creating added value in various economic sectors requires the continuous use of all types of energy sources. For this reason, Algeria has witnessed an increasing consumption of energy, as it rose from about 14 million tons of oil equivalent in 1980 to about 66 million tons of oil equivalent in 2019, i.e. an average annual growth rate of about 4% during the period, with a decrease in 2020 compared to 2019 by 6% due to the decline in economic activity due to the Corona pandemic.

1.1. Research Problem:

In this research paper, we attempt to address a key question:

How does energy consumption affect the environment in Algeria in the short and long run, based on data for the period 1980-2020?

1.2. Sub-questions:

To answer the problem, a set of questions can be posed as follows:

- What other factors, besides energy consumption, can affect the environment?
- Does the environmental impact in Algeria differ in the short and long run?
- How do shocks to energy consumption affect the environment in Algeria?

1.3. Research hypotheses:

We can formulate the following hypotheses to answer the problem and sub-questions

- An increase in energy consumption will lead to greater environmental degradation in Algeria.
- An increase in oil production will contribute to greater environmental degradation in Algeria.
- The environmental impact in Algeria varies between the short and long run.

2. Literature Review:

The energy consumption patterns in Algeria are a critical factor influencing the country's environmental sustainability. The literature on this topic highlights the complex interplay between energy use, economic development, and environmental degradation, underscoring the need for comprehensive policy interventions. This review will explore the impact of energy consumption on the environment in Algeria, focusing on the key sectors driving energy use, the environmental consequences, and potential solutions for a more sustainable energy future.

2.1. Energy Consumption Trends and Sectorial Contributions:

Several studies have analyzed the energy consumption trends in Algeria, revealing the dominant sectors driving energy demand. A study by Zerroug et al. examined the total final energy consumption (TFC) for various sectors, including industry, transport, and agriculture, during the period of 1998-2008. The study found that in 2007, the TFC reached 20 million T-OE, with a per capita consumption of 1,058.0 kg of oil equivalent per person. This figure significantly surpassed that of Morocco (458 kg-OE) and Tunisia (843 kg-OE), highlighting Algeria's higher energy consumption levels.

Further analysis by Zerroug et al. delved into the energy consumption trends within specific industry segments, including building materials, residential, and transport. This research highlighted the substantial energy consumption associated with these sectors¹. A separate study by Boukarta and Berezowska-Azzag underscored the significant role of transportation in Algeria's energy consumption, highlighting it as the second largest energy consumer sector after housing. This study also identified various socio-economic and built environment factors influencing commuting energy demand, including building density, age of respondents, number of cars per household, and round-trip frequency².

2.2. Environmental Impacts of Energy Consumption:

The environmental consequences of Algeria's energy consumption are significant and multifaceted. A study by Mesagan and Olunkwa investigated the impact of energy consumption and capital investment on environmental degradation in several African countries, including Algeria, between 1981 and 2017. The study concluded that energy consumption positively affects carbon emissions in Algeria, contributing to environmental degradation³.

A study by Ibrahim examined the dynamics of energy consumption, economic growth, and population growth on carbon dioxide emissions in nine leading African economies, including Algeria, between 1990 and 2011. The study concluded that energy consumption is a significant contributor to environmental pollution in Africa⁴.

2.3. Sector-Specific Impacts and Mitigation Strategies:

The environmental impacts of energy consumption vary across different sectors. The fertilizer production sector in Algeria is a significant contributor to greenhouse gas emissions. A study by Redouane et al. assessed the environmental impacts of the fertilizer production process, finding that ammonia production alone required substantial energy inputs and generated significant CO₂ emissions⁵. This study highlights the need for energy efficiency improvements and cleaner production methods within the fertilizer industry.

A study by researcher A.Zaidi using the ARDL model showed that the transportation sector plays a fundamental role in energy consumption⁶.

The building sector, particularly hotels, is another key contributor to energy consumption and environmental degradation. A study by Kihal et al. emphasized the high-energy consumption of hotel establishments and the need for sustainable solutions, particularly those related to passive design strategies. The authors highlighted the potential of passive strategies to reduce energy consumption in hotels located in humid Mediterranean climates, common in Algeria⁷.

2.4. The Role of Renewable Energy and Policy Interventions:

The literature highlights the potential of renewable energy sources in mitigating the environmental impact of energy consumption in Algeria. A study by Boukli Hacene et al. examined the use of renewable energies in Algeria, focusing on the building and transportation sectors. The study identified both financial and socio-cultural barriers to the widespread adoption of renewable energy. Despite government efforts to promote renewable energy, the authors concluded that more comprehensive policy interventions are needed to overcome these barriers⁸.

Another study by Boukli and Chabane Sari examined the energy-efficient design optimization of a bioclimatic house in Algeria. The authors emphasized the importance of building performance simulation analysis and ecological energy-saving methods to minimize energy consumption. This study highlights the potential of incorporating sustainable design principles into new and existing buildings to reduce energy demand and environmental impact⁹.

2.5. African context :

Some case studies in the African context compared to what exists in Algeria, we find a study by researcher K.Yaya (2015), "An econometric study of the Long-run determinants of carbon emissions in Cote d'Ivoire". This study was concerned with trying to determine the determinants of carbon emissions in the long run for the country of Côte d'Ivoire, using the cointegration test on statistical data for the period 1970-2010. The researcher concluded that the most important determinants are per capita income, the share of the industrial sector in the gross domestic product, as well as the degree of trade openness¹⁰.

Another study by J.Esso, K.Yaya, "Energy consumption, economic growth and carbon emissions : Cointegration and causality evidence from selected African countries". This study focused on testing the relationship between energy consumption, economic growth, and carbon emissions on a sample of 12 African countries. The empirical results based on

the statistical data of the study variables for these countries for the year 2014 showed that in the long-run, both energy consumption and economic growth are consistent with the increase in carbon emissions. Granger tests also showed that economic growth causes carbon emissions in the short-run in Benin, the Democratic Republic of the Congo, and Ghana¹¹.

The literature on energy consumption and its environmental impact in Algeria reveals a complex and multifaceted challenge. While the country has significant energy resources, the current energy consumption patterns are leading to substantial environmental degradation. The studies reviewed highlight the importance of addressing energy consumption in key sectors such as industry, transportation, and agriculture. To mitigate the environmental impact of energy consumption, Algeria needs to invest in energy efficiency measures, promote renewable energy sources, and implement comprehensive policy interventions to overcome the existing barriers to sustainable energy practices.

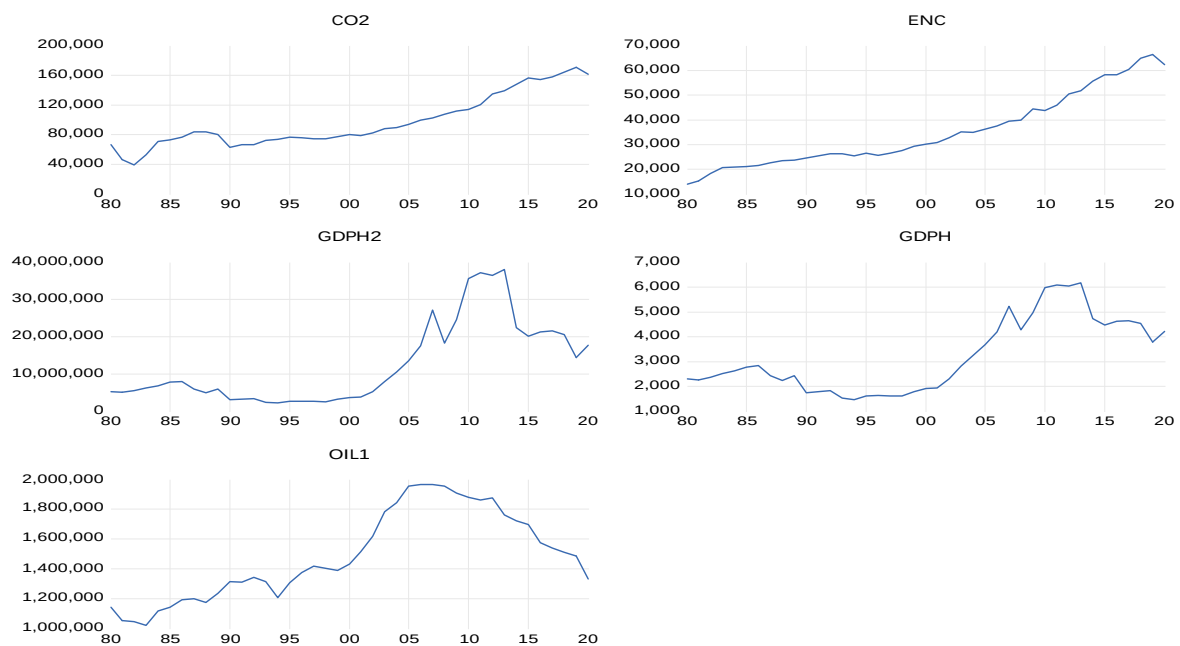
3. Data and Model:

This study relied on data from international databases such as the International Monetary Fund database, the National office of Statistics (Algeria), and the Ministry of Energy and Mines (Algeria), covering the period from 1980 to 2020. This sample was chosen because the data has different starting and ending points, and this sample is considered the best representation of statistics. It includes a set of variables that affect the environment in general or carbon dioxide in particular, which represents the environmental variable. These variables include energy consumption data in Algeria such as electricity and others, which is ENC, in addition to economic growth GDPH, which are measured by the annual growth rate and we add the variable GDPH² based on the environmental Kuznets curve.

3.1. Graph representation of variables:

For the purpose of statistical study and to clarify the form of evolution for the various study variables, we can use the graphic forms as follows:

Figure N° 1: the evolution for the various study variables



Source :Author's plot using National office of Statistics (Algeria) data

From the graph, we note that both carbon emission (CO_2) and energy consumption saw steady increases throughout the study period. The per capita (GDPH) grew between 1995 and 2010, before beginning to decline after 2014. Oil production, which had been on the rise between 1985 and 2005, began to decline until the end of the period.

3.2.Study of dispersion of variables:

In studying the dispersion of variable values, we will rely on a Box-plot that summarizes the distribution of variables according to the median, the first quartile and the third quartile .This is to determine whether there are any outliers for the study variables.

Through above graphs (**Figure N°1 .Appendix**) we observe that there are no outlier points in our sample.

3.3.Descriptive Statistic:

Based on the previous theoretical background, we have chosen the variables and analyzed their relationship in one country Algeria and we start with the table of descriptive statistics:

Table N°.1- Descriptive statistics of study variables

	CO_2	ENC	GDPH^2	GDPH	OIL
Mean	96383.76	35231.66	12372769	3200.031	1485037.
Median	82404.00	30115.00	6852487.	2617.725	1417240.
Maximum	170582.0	66472.00	38002844	6164.645	1967545.
Minimum	39270.00	13917.00	2150753.	1466.545	1018000.
Std. Dev.	35414.10	14805.91	10953260	1478.473	297770.3
Skewness	0.741391	0.699450	1.054969	0.620581	0.249009
Kurtosis	2.416690	2.300026	2.970628	2.090153	1.787057

Jarque-Bera	4.337281	4.180096	7.606700	4.045854	2.937055
Probability	0.114333	0.123681	0.022296	0.132268	0.230264
Sum	3951734.	1444498.	5.07E+08	131201.3	60886499
Sum Sq. Dev.	5.02E+10	8.77E+09	4.80E+15	87435297	3.55E+12

Source: Author's computation using International Monetary Fund database

This table helps us to understand each variable, where the mean and standard deviation show that CO_2 , $GDPH$, $GDPH2$ and enc have the highest annual average and volatility during the period of time, and skewness values indicate that at least 4 variables are skewed to the right, but the kurtosis values show that all variables are normally distributed which is confirmed by the statistic of Jarque-Bera.

3.4. The MODEL :

Our model contains all variables that have an impact on the CO_2 and here we can propose this linear econometric model:

$$CO_{2t} = \beta_0 + \beta_1 ENC_t + \beta_2 GDPH_t + \beta_3 GDPH_t^2 + \beta_4 OIL_t + \varepsilon_t$$

t signifies the time, $t=1, \dots, T$

Where: CO_2 is the carbon dioxide emissions, ENC is the energy consumption, $GDPH$ is the individual gross domestic product, the OIL is the production of oil and $GDPH^2$ is the square of $GDPH$ and ε_t is the term for errors, β_0 to β_4 are the coefficients.

3.5. The ARDL MODEL:

This model is used to check for a long-run relationship, and the following ARDL is constructed based on the hypotheses to search the long-run relationships:

$$\begin{aligned} \Delta CO_{2t} = & \varphi_0 + \varphi_1 \Delta CO_{2t-1} + \varphi_2 \Delta ENC_{t-1} + \varphi_3 \Delta GDPH_{t-1} + \varphi_4 \Delta GDPH_{t-1}^2 \\ & + \varphi_5 \Delta OIL_{t-1} \\ & + \sum_{i=1}^r \beta_{1i} \Delta CO_{2t-i} \\ & + \sum_{i=1}^r \beta_{2i} \Delta ENC_{t-i} \\ & + \sum_{i=1}^r \beta_{3i} \Delta GDPH_{t-i} + \sum_{i=1}^r \beta_{4i} \Delta GDPH_{t-i}^2 + \sum_{i=1}^r \beta_{5i} \Delta OIL_{t-i} + \varepsilon_t \end{aligned}$$

Where β_{1i} to β_{5i} ; ($i = 1, \dots, r$) and φ_j ; $j = 1, \dots, 5$ are employed to examine carefully the long-run relationship.

The ARDL model used in this study was proposed by Pesaran et al 1999, this model can be used for a mix series $I(0)$ (integrated at zero order) and $I(1)$ (integrated at first order)¹².

The short-run ARDL model is written as:

$$\begin{aligned} CO2_t = & \gamma_0 + \sum_{i=1}^r \beta_{1i} \Delta CO_{2t-i} \\ & + \sum_{i=1}^r \beta_{2i} \Delta ENC_{t-i} + \sum_{i=1}^r \beta_{3i} \Delta GDPH_{t-i} + \sum_{i=1}^r \beta_{4i} \Delta GDPH_{t-i}^2 \\ & + \sum_{i=1}^r \beta_{5i} \Delta OIL_{t-i} + \varphi EC_{t-1} + \varepsilon_t \end{aligned}$$

β_{1i} to β_{5i} indicate the short –run coefficients, and φ represents the coefficient of error correction term EC which is generally negative and significant; indicating that every shock will be corrected (to balance) in the next period.

4. Results and discussion:

In this paragraph we review and discuss the results:

4.1. Stationary of variables:

Before estimating the model , we first need to check for stationary using Phillips Perron (PP) test¹³ and Augmented Dickey-Fuller (ADF) test¹⁴.

The table (**Table No.1 in the appendix**) shows the stationary of each variable based on one the result of two test (PP) and (ADF), we find that the all series are not stationary at level. The (PP) and (ADF) results show that all variables are significant at the first difference $I(1)$, at sum up we can affirm that the ARDL model can be used.

Because the all variables are $I(1)$, we will try to examine if there is long-run a relationship between the variables¹⁵.

4.2. Identification of the model:

Using the Akaike information criteria (**Figure2 in Appendix**), a model can be defined as ARDL(3,3,3,3,2)

The figure presents the Model ARDL, which is an ARDL(3,3,3,3,2) and the table (**TableN°2 in the appendix**) shows the parameters estimation.

The results show that the statistics related that the most of the coefficient of the variables are below the 5% even 1% except for $GDPH$, CO_2 (-3), ENC (-1), $GDPH^2$ they are not significant. The quality of adjustment is well because R square is equal 99 % shows that the global variability is explicated by the chosen variables.

4.3. The Bound test :

The bound test is used to confirm the existence relationship of long-run or not, the table shows the results of the bound test, which indicate a long run correlation exists among the variables, as the F-statistic value at 5% levels is greater than upper bound, the same applies to the t-statistic¹⁶.

Table N°2.The bound test of the model

<i>Test Statistic</i>		<i>Value</i>					
<i>F-statistic</i>		12.313441					
<i>t-statistic</i>		-4.813788					

<i>Sample Size</i>	10%		5%		1%	
	<i>I(0)</i>	<i>I(1)</i>	<i>I(0)</i>	<i>I(1)</i>	<i>I(0)</i>	<i>I(1)</i>
<i>F-Statistic</i>						
35	2.696	3.898	3.276	4.630	4.590	6.368
40	2.660	3.838	3.202	4.544	4.428	6.250
Asymptotic	2.450	3.520	2.860	4.010	3.740	5.060
<i>t-Statistic</i>						
Asymptotic	-2.570	-3.660	-2.860	-3.990	-3.430	-4.600

* I(0) and I(1) are respectively the stationary and non-stationary bounds.

Source: Author's computation using Eviews 13

4.4. The Error correction term:

After estimating the proposed ARDL model, which includes the error correction term and the short-run relationship, as shown in the table (**Table N°3 in the appendix**).

The estimated coefficient of EC is negative that it confirms the existence of an error correction mechanism. This coefficient represents the degree to which the variable CO₂ will be drawn back toward the long-run target, it is estimated at -0,41 indicating a relatively rapid adjustment to the long-run target approximately, two years.

4.5.The Coefficient of long-run:

The long -run parameters (coefficient) can be extracted from the estimated model as follows (table N°4 in the appendix):

$$CO_2 = 1.981894*ENC+ 0.000222*GDPH2+8.173496*GDPH- 0.025945*OIL1$$

This result shows that, in long-run ENC has a positive relationship with the CO₂ this can be explained by that fact that the long–run growth dynamic of energy consumption due to the new dynamic of market.

As for GDPH, it is also positive correlated with the CO₂ simply interpret because an increase in production leads to an increase in CO₂ but the relationship is weakly negative with the OIL because when the oil products falls the factory of fuels and others increase its production.

4.6.The Diagnostic Analysis:

To rely on the estimation results of the model, additional tests must be conducted on the model's goodness. The following table shows these tests:

Table N°3. Diagnostic tests

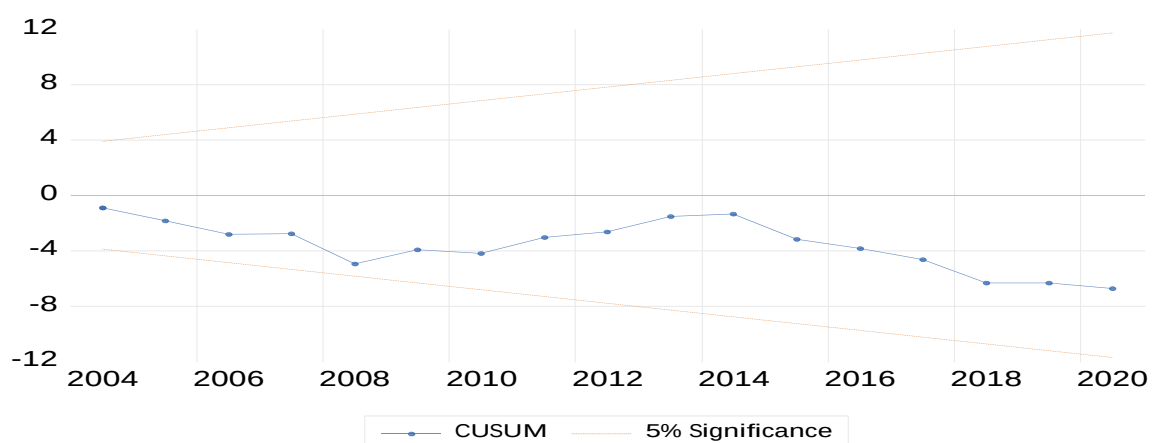
<i>Diagnostic test</i>	<i>Null Hypothesis</i>	χ^2 (P-value)	<i>Decision</i>
<i>Breusch-Godfrey LM</i>	<i>H0: No serial correlation</i>	0,1643	<i>Do not reject H0</i>
<i>Breusch-Pagan-Godfrey</i>	<i>H0: Homoskedasticity</i>	0,5947	<i>Do not reject H0</i>
<i>Jarque-Bera test</i>	<i>H0: Residuals are normally distributed</i>	0,057236	<i>Do not reject H0</i>
<i>Ramsey RESET Test</i>	0,2337 > 0,05 F-VERSION		<i>stable and good specification</i>

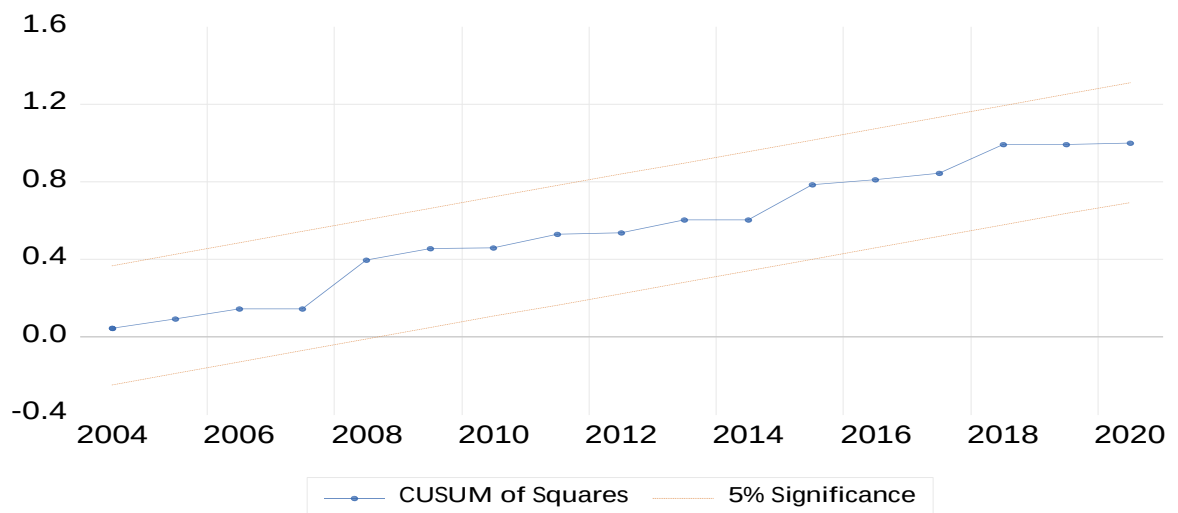
Source: Author's computation using Eviews 13

From the table above finding the tests summarized, from all these test we can validate the model, furthermore, the displayed results indicate that the probability associated with each test is higher than 5% threshold, which leads to accept the null hypothesis: absence the heteroscedasticity, and autocorrelation and the error normality is accepted, in addition the probability associated with the Ramesy specification test is higher than 5% threshold , allowing us to conclude that the model is well specified.

And with the figures below we can confirm that the result of the CUSUM and CUSUMQ tests show that the residuals exhibit the desired properties.

Figure N°2. The CUSUM curve and the CUSUM of Squares curve





Source: Author's computation using Eviews 13

The estimation of the ARDL model as an attempt to measure the impact of energy consumption on environmental conditions, expressed by carbon dioxide (CO₂) emissions volume, using data from the Algerian economy and including both individual GDP (GDPH) and oil production (OIL) as external variables contributing to determining carbon emissions, and after conducting the necessary statistical and econometric tests, a statistically acceptable model was reached, especially with the high value of the coefficient of determination indicating that 99% of carbon emission volume changes are determined by the external variables included in the model. The bounds test showed that there is a cointegration relationship between variables, and carbon emission volume has a relationship with its determinants in both short and long run, with an adjustment speed to the long term equaling 41%, meaning the adjustment process and return to equilibrium takes about two and a half years (2.5 years) as indicated by the error correction term parameter Cointeg(-1) which was negative (-0.41) and statistically significant at 1% error rate.

Regarding short-run results, the estimated model indicates that energy consumption positively affects carbon emissions, where every one-unit increase in energy consumption raises carbon emission volume by about 0.58 units, meaning energy consumption negatively affects environmental conditions in Algeria in the short run. Individual GDP (individual income) has no instantaneous effect but has a positive effect after two periods on emission volume, while squared individual GDP has an effect after two periods but with an inverse relationship, indicating the verification of the Environmental Kuznets Curve theory. As for oil production quantities, they have a positive impact on carbon emission volume but with a weak coefficient estimated at 0.028 units of carbon emitted due to producing an additional unit of oil.

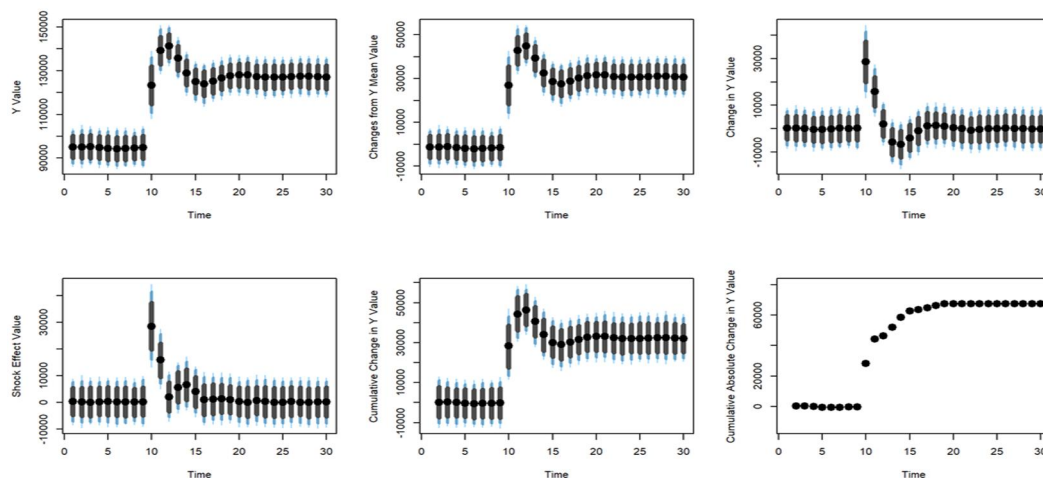
Regarding the long run, the model indicates that all parameters of explanatory variables are statistically significant except for the squared individual income variable, which was insignificant. Energy consumption has a positive effect on carbon emission volume, where a one-unit increase in energy consumption causes a 1.98 unit increase in

carbon emissions. The same result was recorded for individual income, which also had a positive effect where a one-unit increase in individual income leads to an 8.17 unit increase in carbon emissions. As for oil production, the model showed that it has an inverse relationship with carbon emission volume, albeit with a relatively weak coefficient estimated at about 0.026. This inverse relationship began to appear especially in recent years where we observed a relative decline in oil production with a continuous increase in carbon emission volume, indicating that there are other factors contributing to increased emissions, such as energy consumption, especially as Algeria began adopting economic diversification policies and encouraging both local and foreign investment in economic sectors outside the hydrocarbon sector.

4.7. Dynamic ARDL model:

There are certain conditions that must exist to apply this model such as the dependent variable being integrated of order one and the independent variables being either integrated at order zero, order one or a combination between two last orders of integrations¹⁶, and because our dependent and independent variables meet the conditions and are cointegrated. All these conditions are satisfied. The dynamic ARDL simulation is used to examine the long and short run effects of variables chosen on the CO₂.

Figure N°3. The impulse response graph



Source: Author's computation using Eviews 13

Through the data, we will see how and to what extent the dependent variable - in our case, carbon emissions (CO₂) - responds when a shock occurs in the independent variable, which is energy consumption (ENC), by one standard deviation at a single significant point over a 30-year period. Looking at the first curve specific to emission values, we see a slight increase extending for 10 years when a shock occurs, then it becomes larger to decrease or decline slightly before stabilizing again, but at a higher level. This proves that when a shock occurs in energy consumption, it will lead to a significant increase in emissions.

In the second curve, which shows the expected model changes from the average emissions variable, it is approximately similar to the first curve with the same interpretation. We noticed that the shock did not dissipate much as we mentioned earlier and maintains a higher level, and here the shock has permanent effects since it did not return to the first average.

As for the third curve, which expresses changes in the dependent variable's value due to the shock, we notice that there is a sequence of shock that rises after 10 years, then decreases again below the previous average and returns after approximately 17 years to the previous initial state for ten years and stabilizes.

In the fourth curve, we notice that there is continuity in the shock where it equals zero then rises after 10 years at its peak, to return to slightly above average, rising slightly for four years before returning to equal zero.

The fifth curve shows the total effects of the shock, we see a slight increase extending for 10 years when a shock occurs, then it becomes larger to decrease or decline slightly before stabilizing again, but at a higher level. This proves that when a shock occurs in energy consumption, it will lead to a significant increase in emissions. These findings indicate that increases in ENC contribute to an increase in CO₂.

In summary, these findings suggest that ENC (Energy Consumption) is a crucial factor impacting environmental quality in Algeria. Therefore, all sectors, with support from the government, should invest in initiatives aimed at reducing ENC to help alleviate negative effects on environmental quality. Additionally, the government should consider implementing policies to support and encourage the adoption and practical application of these technologies.

5. Conclusion :

The study has explored the relationship between Algeria's energy use, economic factors, and environmental degradation. It uses an ARDL model to analyze the influence of various energy sources, economic variables on CO₂ emissions, relying on data from 1980 to 2020. The results of the study show that both the first and third hypotheses are correct, but the second hypothesis is incorrect, this can be explained as follows.

The study confirmed a significant long-run relationship between CO₂ emissions and the examined variables through bound testing and Energy consumption (ENC) shows a strong positive correlation with CO₂ emissions in the long run, on the other hand the GDP per capita (GDPH) demonstrates a positive relationship with CO₂ emissions and the Oil production shows a weak negative correlation with CO₂ emissions.

The research findings indicate that Algeria's energy consumption patterns significantly contribute to environmental degradation. Additionally, the country's economic growth has been consistently associated with increased carbon emissions. Based on the research results, the study offers several key recommendations to address these challenges:

Firstly, the study calls for energy policy reform. This includes implementing comprehensive energy efficiency measures across all sectors, developing and enforcing stricter environmental regulations for industrial operations, and introducing incentives to promote the adoption of clean energy in both the industrial and residential sectors.

Secondly, the study emphasizes the need for sustainable development strategies. This involves diversifying the economy beyond its heavy reliance on the hydrocarbon sector, investing in renewable energy infrastructure and technology, and promoting green building standards and sustainable urban planning. In the transportation sector, the study recommends modernizing public transportation systems, encouraging the adoption of electric vehicles, and implementing urban planning strategies that reduce commuting energy demand.

The study also highlights the importance of industrial innovation. This includes investing in R&D for energy-efficient industrial processes, promoting the use of clean production technologies in high-energy-consuming industries, and developing incentives for industries to adopt environmentally friendly practices. At the policy framework level, the study suggests strengthening environmental monitoring and enforcement mechanisms, developing comprehensive climate action plans with specific emission reduction targets, and creating financial mechanisms to support the adoption of green technologies.

Finally, the study underscores the need for enhanced international cooperation. This involves actively participating in international climate agreements, seeking technical and financial support for environmental projects, and sharing best practices with other developing nations facing similar challenges.

These multifaceted recommendations aim to balance Algeria's economic growth with environmental sustainability, addressing the country's specific challenges in reducing carbon emissions and promoting sustainable development.

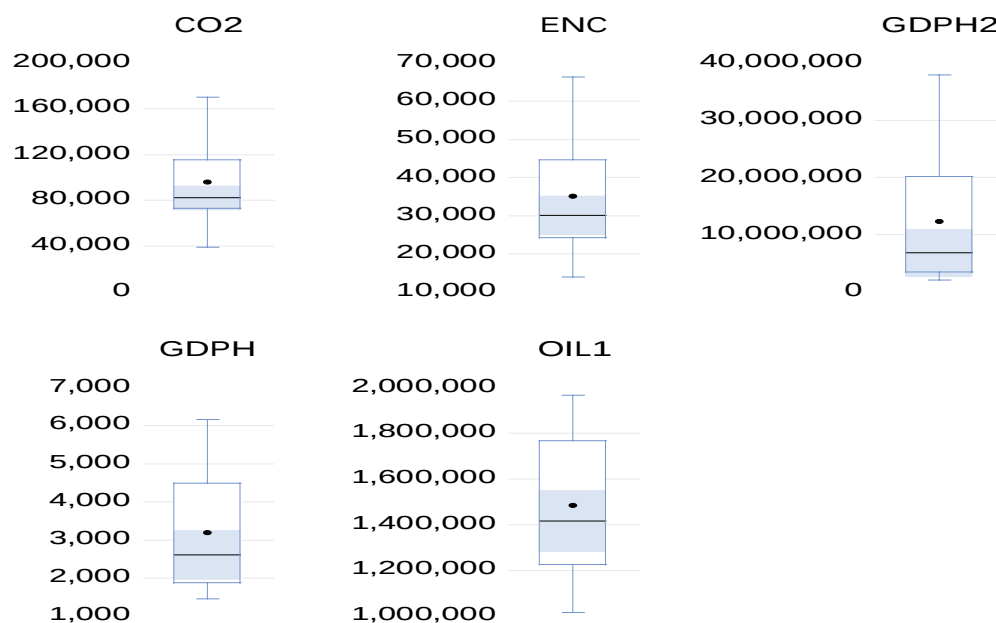
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7. Appendix:

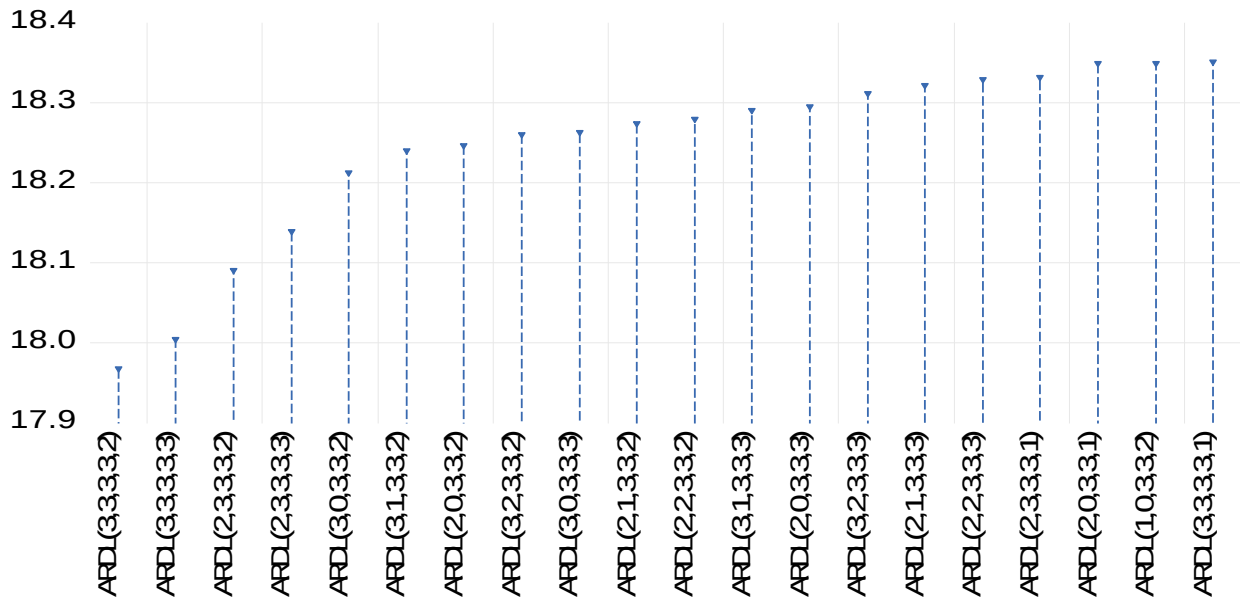
Figure N°1: The Box-plot of study variables



Source: Author's computation using IMF data

Figure °2. The Akaike Information Criteria to identified the ARDL model

Akaike Information Criteria (top 20 models)



Source: Author's computation using IMF data

Table N° 1. The Unit Root Test Table (Phillips- Perron)

		At Level				
		CO ₂	ENC	GDPH	GDPH2	OIL
With Constant	t-Statistic	0.5428	0.6491	-1.1012	-1.3110	-1.2972
	Prob.	0.9862	0.9894	0.7061	0.6151	0.6216
		n0	n0	n0	n0	n0
With Constant & Trend	t-Statistic	-2.0598	-1.0493	-1.6974	-1.8325	0.2056
	Prob.	0.5516	0.9250	0.7339	0.6700	0.9973
		n0	n0	n0	n0	n0
WithouConstant& Trend	t-Statistic	2.2940	4.6057	0.1123	-0.5193	0.0297
	Prob.	0.9939	1.0000	0.7126	0.4854	0.6864
		n0	n0	n0	n0	n0
		At First Difference				
		d(CO ₂)	d(ENC)	d(GDPH)	d(GDPH2)	d(OIL)
With Constant	t-Statistic	-5.3387	-4.7394	-5.8182	-5.9972	-3.7147
	Prob.	0.0001	0.0004	0.0000	0.0000	0.0076
		***	***	***	***	***
With Constant & Trend	t-Statistic	-5.0207	-4.8627	-5.7411	-5.9146	-4.1783
	Prob.	0.0012	0.0018	0.0002	0.0001	0.0109
		***	***	***	***	**
Without Constant & Trend	t-Statistic	-4.6693	-3.3733	-5.8343	-6.0533	-3.7445
	Prob.	0.0000	0.0013	0.0000	0.0000	0.0004
		***	***	***	***	***
UNIT ROOT TEST TABLE (ADF)						
		At Level				
		CO ₂	ENC	GDPH	GDPH2	OIL
With Constant	t-Statistic	0.4876	0.6480	-0.9364	-1.2390	-1.6087
	Prob.	0.9842	0.9894	0.7661	0.6480	0.4687

		n0	n0	n0	n0	n0
With Constant & Trend	t-Statistic	-1.9210	-1.0788	-1.4442	-1.6647	0.9357
	Prob.	0.6251	0.9201	0.8319	0.7483	0.9998
		n0	n0	n0	n0	n0
Without Constant & Trend	t-Statistic	2.1721	4.6057	0.2067	-0.4695	0.0170
	Prob.	0.9918	1.0000	0.7411	0.5058	0.6822
		n0	n0	n0	n0	n0
<u>At First Difference</u>						
		d(CO2)	d(ENC)	d(GDPH)	d(GDPH2)	d(OIL)
With Constant	t-Statistic	-5.3387	-4.8418	-5.7829	-6.0019	-3.6021
	Prob.	0.0001	0.0003	0.0000	0.0000	0.0102
		***	***	***	***	**
With Constant & Trend	t-Statistic	-5.0207	-4.6514	-5.7016	-5.9212	-4.2230
	Prob.	0.0012	0.0033	0.0002	0.0001	0.0097
		***	***	***	***	***
Without Constant & Trend	t-Statistic	-4.6306	-1.2011	-5.7943	-6.0480	-3.6334
	Prob.	0.0000	0.2060	0.0000	0.0000	0.0006
		***	no	***	***	***

Notes : * Significant at the 10% level ; ** Significant at the 5% level ; *** Significant at the 1% level.

Table N°2. The ARDL model

Variable	Coefficient	t-Statistic	Prob.
CO ₂ (-1)	0.793760	8.918518	0.0000***
CO ₂ (-2)	-0.362839	-3.197410	0.0053***
CO ₂ (-3)	0.150240	1.806894	0.0885*
ENC	0.577541	1.768855	0.0949*
ENC(-1)	0.008232	0.021498	0.9831
ENC(-2)	-0.801204	-2.054343	0.0556*
ENC(-3)	1.045525	2.645266	0.0170**
GDPH2	0.000327	0.742954	0.4677
GDPH2(-1)	-0.000477	-0.807097	0.4308
GDPH2(-2)	-0.001792	-2.973800	0.0085***
GDPH2(-3)	0.002035	4.176005	0.0006***
GDPH	-4.494943	-1.075344	0.2972
GDPH(-1)	7.485474	1.346992	0.1957
GDPH(-2)	20.44593	3.507518	0.0027***
GDPH(-3)	-20.01309	-4.251489	0.0005***
OIL	0.028659	3.628235	0.0021***
OIL(-1)	-0.063961	-5.355870	0.0001***
OIL(-2)	0.024436	3.048327	0.0073***
D_1990	-17733.11	-6.227243	0.0000***
D_2001	-5583.578	-3.004373	0.0080***
C	19657.55	5.316294	0.0001***
R-squared	0.998912		
Prob(F-statistic)	0.000000		

Source: Author's computation using Eviews 13

Table N°3. results of estimation

Selected model: ARDL(3,3,3,2)

Variable	Coefficient	t-Statistic	Prob.
COINTEQ*	-0.418839	-8.720872	0.0000***
D(CO ₂ (-1))	0.212599	3.531088	0.0020***
D(CO ₂ (-2))	-0.150240	-3.094453	0.0055***
D(ENC)	0.577541	2.685557	0.0138**
D(ENC(-1))	-0.244321	-0.890159	0.3835
D(ENC(-2))	-1.045525	-3.459558	0.0023***
D(GDPH2)	0.000327	0.881124	0.3882
D(GDPH2(-1))	-0.000243	-0.728360	0.4744
D(GDPH2(-2))	-0.002035	-5.787973	0.0000***
D(GDPH)	-4.494943	-1.277292	0.2154
D(GDPH(-1))	-0.432846	-0.138286	0.8913
D(GDPH(-2))	20.01309	5.937846	0.0000***
D(OIL)	0.028659	4.703738	0.0001***
D(OIL(-1))	-0.024436	-3.557926	0.0019***
D_1990	-17733.11	-6.975282	0.0000***
D_2001	-5583.578	-3.462672	0.0023***
C	19657.55	9.122251	0.0000***
R-squared	0.964754		
Adjusted R-squared	0.937899		
F-statistic	35.92545	Durbin-Watson stat	2.327779
Prob(F-statistic)	0.000000		

* p-values are incompatible with t-Bounds distribution.

Source: Author's computation using Eviews 13

Table N°4. The Coefficient of long- run

Variable *	Coefficient	t-Statistic	Prob.
ENC(-1)	1.981894	16.82726	0.0000***
GDPH2(-1)	0.000222	0.363817	0.7182
GDPH(-1)	8.173496	2.093312	0.0439**
OIL(-1)	-0.025945	-3.950710	0.0004***

Source: Author's computation using Eviews13