ECONOMETRIC MODELLING OF ENVIRONMENTAL DEGRADATION IN ALGERIA DURING THE PERIOD 1972-2021 USING THE ARDL MODEL

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Abstract

The aim of this study is to analyze the issue of environmental degradation in Algeria during the period 1972-2021 by measuring the impact of economic growth, represented by GDP per capita, international trade, energy depletion, population growth rate and urbanization, on the damage caused by carbon dioxide emissions, using the model of Autoregressive Distributed Lag (ARDL). In addition, the study variables were subject to various standard tests. The model presented significant statistics, with a long-term equilibrium.

One of the most important findings of this study is that the approach adopted in Algeria aimed at raising the rate of economic growth is increasingly contributing to the negative impact on the environment.

KEY WORDS: CO_2 emissions; GDP per capita; International Trade; Algeria; ARDL Model.

JEL CLASSIFICATION: F18, Q40, O44.

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نمذجة قياسية للتدهور البيئي في الجزائر خلال الفترة 1972 – 2021 باستخدام نموذج الانحدار الذاتي للفجوات الزمنية المتباطئة ARDL

ملخص

تهدف هذه الدراسة إلى تحليل مشكلة التدهور البيئي في الجزائر خلال الفترة 1972-2021 من خلال قياس أثر النمو الاقتصادي، الذي تم تمثيله بنصيب الفرد من الناتج المحلي الإجمالي، التجارة الدولية، استنفاد الطاقة، معدل النمو السكاني والتحضر، على الأضرار الناجمة عن انبعاثات ثاني أكسيد الكربون، باستخدام نموذج الانحدار الذاتي للفجوات الزمنية المتباطئة ARDL، وبعد اجراء مختلف الاختبارات القياسية لمتغيرات الدراسة كالنموذج ذو جودة وقد تبين وجود توازن طويل الأجل في النموذج المقدر.

ومن بين أهم النتائج المتوصل اليها في الدراسة، أن النهج المتبع في الجزائر الرامي إلى رفع معدل النمو الاقتصادي يسهم بوتيرة متزايدة في التأثير السلبي على البيئة.

كلمات مفتاحية

انبعاثات CO_2، نمو نصيب الفرد من GDP، تجارة دولية، استنفاد الطاقة، الجزائر، نموذج ARDL.

MODELISATION ECONOMETRIQUE DE LA DEGRADATION DE L'ENVIRONNEMENT EN ALGERIE DURANT LA PERIODE 1972-2021 A L'AIDE DU MODELE ARDL

RÉSUMÉ

L'objectif de cette étude est d'analyser la problématique de la dégradation de l'environnement en Algérie durant la période 1972-2021 en mesurant l'impact de la croissance économique, représentée par le PIB par habitant, le commerce international, l'épuisement de l'énergie, le taux de croissance démographique et l'urbanisation, sur les dommages causés par les émissions de dioxyde de carbone, en utilisant le modèle autorégressif ARDL. En outre, les variables de l'étude ont été soumises à divers tests standard. Le modèle a présenté des statistiques significatives, avec un équilibre à long terme.

L'un des résultats les plus importants de cette étude est que l'approche adoptée en Algérie visant à augmenter le taux de croissance économique contribue de plus en plus à l'impact négatif sur l'environnement.

MOTS CLÉS: Emissions de CO_2, PIB par habitant, Commerce international, Algérie, Modèle ARDL.

INTRODUCTION

Economic growth and international trade are among the most critical topics of interest in today's economy, on an international level. Climate change is crucial mainly because it is linked to the environmental aspect that has become a significant source of threat to the planet. The environmental situation has become unable to withstand the traditional economic model, which has alerted many traditional economists in their studies of its danger to the environment, such as Thomas Malthus (1766-1834)(Mokaled et al., 2008), David Ricardo (1772-1832), and John Stewart Mill (1806-1873)(Mandour & Nematallah, 1996). The recent experimental literature of Solow, Ramcy-Cass-Koopmans model of environmental pollution, the AK[1] model of economic growth, and the Stockey model of environmental pollution, in addition to the Environmental Kuznets Curve (EKC)(Grossman & Krueger, 1995)(Xepapadeas, 2003), have illustrated the theoretical basis for achieving dynamic models that consider that the economic activity poses a threat on the environment.

Since the effects of environmental threats know no boundaries, Algeria is not isolated from the world; it too suffers from environmental pressure factors, such as demographic growth, desertification, drought and pollution. In fact, Algeria has experienced demographic growth from 10.2 million people in 1960 (Ministry of Environment, 2000)to 44.1 million in 2021, which is a pressure factor on the future of development. In addition, according to the Arab Development Report of 2009, Algeria has lost around 7000 hectares of land due to desertification (United Nations, 2009). Algeria has over 2 million km^2 of land, most of which is desert, and 740381 km^2 is in dry areas.

As for water pollution, companies located in coastal regions are significant contributors since marine and groundwater are contaminated with petroleum waste, radioactive materials, and heavy metals, including lead. In fact, nearly 50% of Annaba's vast water resources are affected by pollution caused by industry (Ministry of Environment, 2000). Moreover, Algeria's economy depends on the production of fossil fuels while exploration, production, refining, and distribution of oil and gas have a significant effect on air quality, especially in areas near oil and gas facilities that release greenhouse gases like carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which are a significant source of air pollution related to oil and gas activities. In addition, these businesses contribute to air pollution by emitting volatile organic compounds (VOCs), sulphur oxides (SOx), and nitrogen oxides (NOx).

To this end, the problem tackled by this study can be formulated as follow: What effect do the economic factors such as economic growth,

[1] The designation AK derives from the most basic form of the models'production functionY = AK. Here A is a positive constant representing theeconomy's level of technology and K is the economy's stock of capital.

international trade, energy depletion, population density, and urban growth, have on the environment in Algeria, as measured by the amount of damage caused by CO_2 emissions? To address this issue, we suggest the following hypothesis: If the Algerian economy continues on its current course, environmental pollution will rise.

This study aims to find and show the nature of the relationship between economic growth, international trade, energy depletion, and the damage caused by CO_2 emissions. This was achieved using an analytical descriptive method to comprehend the theoretical aspects and the resulting relationships between the study variables. In addition, an analytical quantitative method represented by an econometric method of an autoregressive distributed lag (ARDL) model to estimate, test and evaluate the study variables was employed. The study period was from 1972 to 2021 from the first United Nation conference on sustainable development in Stockholm to the latest available data.

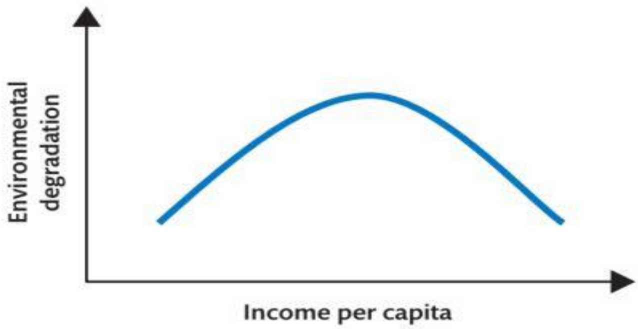
For this purpose, this article is organised as follows: Firstly, a review of previous studies on the subject is presented. Secondly, the model used in the study is described. The results of economic measurements are then presented and analysed, and finally, the study-related conclusions are drawn.

1- LITERATURE REVIEW

Economic progress is generally viewed as a sign of development and improving living conditions. However, this expansion can also have negative environmental consequences, such as increased CO_2 emissions caused by increasing energy use. Many theories emerged based on econometric models to quantify the impacts of anthropological activities on the environment, natural ecosystem and degradation of natural resources. Such econometric models include EKC, Solow and AK.

The EKC is an economic model that defines the relationship between economic growth and environmental damage as an inverted U-shaped curve depicted in Figure 1. This model states that as the economy grows, pollution like CO_2 emissions will initially increase but decrease as incomes rise and environmental concerns grow.

Figure 1. The Environmental Kuznets Curve



Source: (Orsini, 2020)

Many factors explain this inverted U-shaped trend. As a nation's economy expands, it transforms from a framework that heavily depends on resources and contributes to environmental degradation to an eco-friendlier structure, such as the service sector. Then, developed nations often have more capital to invest in less polluting technology and energy infrastructure. Lastly, environmental concerns and societal pressure to minimise pollution rise by taking strict measures. This implies that while the rise in CO_2 emissions is frequently associated with economic growth, it still depends on factors like the structure of the economy, environmental laws, and how technology is used.

Since the seminal research of (Grossman & Krueger, 1991), who were the first to test the EKC hypothesis to analyse the relationship between per capita income and environmental degradation, numerous additional studies have been conducted. The study of (Yefan Zhou et al, 2018) tested the validity of the EKC hypothesis. The results showed that the independent variables impact CO_2 emissions, where energy consumption increases CO_2 emissions. The effects of energy used were more noticeable in developed countries than in developing countries (Kasman & Duman, 2015). Also validated the environmental Kuznets curve theory through a study that determined the causal link between energy consumption, CO_2 emissions, economic development, trade openness, and urbanisation in a panel of new EU member and candidate states from 1992 to 2010.

Although the EKC is an exciting way to examine how economic growth affects CO_2 emissions, its applicability is not universal, as the inverted U-shaped pattern is not consistently observed across all types of pollution or in all countries (Shuyu & Rongrong , 2021) (Lacheheb et al., 2015) (Jian et al., 2022). The Solow model of economic growth is a model that fundamentally embeds the theory of endogenous growth. Environmental pollution is not explicitly considered as a factor influencing economic development in the basic Solow model. The model emphasises on capital accumulation, technological advancement, and labour as the primary long-term generators of economic growth (Sredojević et al., 2016). Nevertheless, environmental degradation can be incorporated into the Solow model through model extensions or additional factors. For instance, firms that generate pollution and waste treatment facilities can be considered as factors that influence labour productivity and investment, thereby impacting economic growth as a whole.

In contrast, there are alternative models that incorporate environmental factors such as pollution and depletion of natural resources into the analysis of economic growth. These environmental models are primarily concerned with estimating the effects of pollution and resource consumption on productivity, investment, and consequently economic growth.

In the AK model, the rate of a country’s long-run growth depends on savings and resource distribution efficiency. The AK model predicts the relationship between government policies, investment rates, and Gross Domestic Product (GDP) growth. Unlike earlier exogenous growth models, the AK model suggests that permanent changes in government policies influencing investment rates should result in permanent changes in a nation's GDP growth (McGrattan, 1998).

All of the above-mentioned theories used various econometric models. A panel vector autoregressive (PVAR) analysis was utilized to evaluate how CO_2 emissions and economic growth in MENA region are affected by energy consumption and financial development. PVAR employs numerous variables to produce a comparison between different countries. (Mikayilov et al., 2018) studied the impact of economic growth on CO_2 emission in Azerbaijan using cointegration model. This model was further developed to produce an ARDL model (Pesaran et al., 2001).

(Hossain, 2012) employed this ARDL model to determine the link between CO_2 emissions, energy consumption, economic development, international trade, and urban expansion from 1960 to 2009. The study demonstrated a short-run, one-way causal association between energy consumption, trade openness, CO_2 emissions, trade openness, energy consumption, CO_2 emissions, and economic growth. The research offers evidence for a long-run link between the analyzed variables, which is compatible with the results of the cointegration tests conducted by Johansen. The study concluded that Japan's high energy use causes CO_2 emissions to increase over time, thereby causing more damage to the environment. Still, the main drive for long-run economic growth, trade openness, and urban growth is the quality of the environment.

(Tariq et al., 2018) used the ARDL panel model to investigate the possible environmental and economic implications of foreign direct investment and trade liberalisation in Pakistan and India, as well as whether trade liberalisation affects their environment. Foreign direct investment and CO_2 emissions have a favourable long-run association. However, trade openness negatively influenced CO_2 emissions in Pakistan and India.

The case of Algeria has been analyzed by several studies.(Bouznit & María , 2016) tested the EKC hypothesis in Algeria from 1970–2010 and validated the Kuznets curve. (Touitou & Langarita, 2021) also analyzed the case of Algeria for the period between 1973–2016 and found an inverted U-shaped curve. In a recent study (Ayad et al., 2023), the effect of socioeconomic factors on environmental quality were estimated in Algeria, by re-examining the EKC model and incorporating the ARMEY curve and the STIRPAT model. They found an inverted U-shaped curve for each the models used.

The ARDL model was also used in a study by (Lacheheb et al., 2015), who found that EKC hypothesis was not satisfied when investigating the relationship between economic growth and CO_2 emission in Algeria. This study did not take in consideration population growth and urbanization. Therefore, it seems that the evidence is mixed regarding the presence of a U-shaped EKC curve in Algeria.

2- OVERVIEW OF ENVIRONMENTAL DEGRADATION IN ALGERIA

Numerous factors affect the degradation of the environment in the world and particularly in Algeria. In the following subsections, we present such factors which are particular to our study topic.

2.1- Algeria's economic growth

Algeria's economy depends significantly on hydrocarbon exports, particularly oil and natural gas. Hydrocarbons account for over 95% of Algeria's exports and 60% of the country's budget revenue. In fact, Algeria's total oil and natural gas liquids production reached 1,287 thousand barrels per day in 2021, producing exports of petroleum worth 12,423 million dollars (OAPEC, 2022). Algeria's economic growth depends significantly on how much oil and natural gas cost. When oil and petrol prices are high, Algeria's economy experiences robust expansion. In contrast, a fall in these prices degrades the economy. For example, the decline in oil prices in 2014 slowed real GDP growth in 2015 from 3.8% in 2014 to 2.1% in 2015. Similarly, the price recovery in 2016 allowed the Algerian economy to accomplish a 3.3% growth. Increasing production often means using more energy. When these fossil fuels are burned out, they release greenhouse gases like CO_2 that contribute to environmental degradation.

To guarantee sustained growth, Algeria must expedite the implementation of economic diversification plans to build industries other than fossil energy, by putting more effort into agriculture, tourism, services, and renewable energy, among other sectors.

2.2- Algeria's demographic growth

Algeria's population has tripled since 1972, from 15 million in 1972 to over 44 million in 2021. Due to the ongoing population expansion and urbanisation centralized in the north of the country, this situation is predicted to worsen in the coming years. According to forecasts, Algeria's population might exceed 50 million by 2030 and 64 million by 2050 (PRB, 2018), exerting significant environmental pressure.

This fast population expansion has major negative environmental effects due to the continuous need for housing, food, energy, and transportation. In fact, the construction of new buildings and infrastructure degrades natural spaces and damages biodiversity. Therefore, Algeria must strengthen its agriculture to satisfy these demands, in order to prevent deforestation and land degradation.

In essence, energy usage and CO_2 emissions per capita have also increased substantially. From 2000 to 2017, energy usage per capita grew by 62% and CO_2 emissions by about 90%. i.e. 1.30 tonne per person to 2.46 tonne per person.

2.3- International trade

International trade has a considerable effect on Algeria's CO_2 emissions and on the country's economy as a whole. Algeria is a net exporter of energy, therefore its exports of oil and natural gas cause CO_2 to be released into the atmosphere. In fact, Algeria's energy-related CO_2 emissions made up 68% of the country's total CO_2 emissions in 2018.

The trade surplus in 2019 was $16.8 billion. International trade has a significant impact on both Algeria's economy and ecology. On the one hand, it greatly adds to the nation's CO_2 emissions, and on the other, it is critical for the country's export earnings, essential imports, and employment. To guarantee sustainable growth, Algeria must consider the influence of its foreign commerce on the climate and implement ecologically friendly legislation.

2.4- Energy consumption

Algeria's energy usage has increased significantly since gaining independence in 1962. Between 1972 and 2021, the primary energy consumption grew by a factor of 25, from 2.4 millions of tonnes of oil equivalent (Mtep) to 60 Mteps. Its sustained energy expansion was mostly attributable to the utilisation of hydrocarbons (oil and gas), which account for more than 95% of Algeria's extracted energy resources.

This dependency on fossil fuels results in significant greenhouse gas emissions and air pollution, particularly in major cities. In fact, more than 160 million metric tonnes of CO_2 is annually produced, making Algeria one of Africa's major polluters. Fine particles and ozone pollution have reached alarming levels and have major health effects on the population. As the 2023 United Nations Climate Change Conference (COP28) in Dubai approaches, Algeria must give priority to using its enormous clean renewable energy resources including solar, wind, geothermal and green hydrogen energy to reduce its environmental footprint and safeguard the health of its residents.

2.5- Urbanisation

Algeria's urbanisation has undergone substantial changes since the country's independence in 1962. During the first three decades following independence, the population was spread around both urban and rural areas. During Algeria's black decade, more people started migrating to the urban regions, resulting in anarchical urbanisation. Thereafter, Algeria has experienced a substantial increase in its urban population; thus, urbanisation has become a crucial aspect of its economic and social development. The government has made substantial investments in infrastructure initiatives, such as building new cities and expanding existing ones. However, Algeria's accelerated urbanisation has significantly strained its natural resources, including land, water, and energy. Due to the increased demand for housing, transportation, and public services, agricultural land and natural habitats have been converted into urban areas, resulting in habitat loss and fragmentation. In addition, the discharge of untreated sewage and industrial effluents into rivers and other water bodies has primarily led to the degradation of water resources.

Since 2001, Algeria fostered the idea of environmental legislation, like waste management, sustainable development, management of natural resources, water resource preservation and natural habitats conservation. In addition, new governmental institutions were established to ensure the implementation of such legislations.

3- METHODS

3.1- Data sources

In this section, we will conduct an econometric analysis to measure the impact of economic growth, energy use, population density, urbanisation, and trade on Algeria's contribution to environmental pollution as measured by the carbon dioxide emissions index for the period between 1972 and 2021. The idea of sustainable development was born and fostered by the international community in 1972. The year 2021 was chosen as the endpoint of this study due to the availability of open-source data gathered from the World Bank's website. The study variables includes GDP, ENGY, DENS, URB and TRD[1], the annual carbon dioxide emissions (per capita) data[2] from 1972 to 2021. Since the ENGY variable in the database is only available from 1972 to 2014, we used the ETS SMOOTHING method to predict the values from 2015 to 2021.

3.2- Model specification

The ARDL model established by (Pesaran et al., 2001) was used to estimate the variables' short- and long-run parameters. This model is called autoregressive because lagged values of the dependent variable appear as regressors as well, and it has distributed lag because the effect of X and Z on Y is spread over a period of time from t - m to t. This model is known to be dynamic because it examines the behaviour of a variable over time. After estimating the model, the

[1] https://databank.worldbank.org/

[2] https://ourworldindata.org

appropriate tests were applied (Demitrios & G. Hall, 2011). Among the distinguishing characteristics of the ARDL model (Zorbami, 2016)are the following:

- ✓ It takes a sufficient number of time lags to obtain the best data set for the general framework model.
- ✓ It has better properties in the case of short time series compared to other standard tests for co-integration.
- ✓ It provides better results for short-run parameters, separates short and long run effects, and offers reliable diagnostic tests.
- ✓ The estimated parameters in the short- and long-runs are more consistent than those in the Engle-Granger methodology.

In order to model the relationship between the variables under study, and based on the formal studies conducted on the subject, the study variables were restricted to six variables, which are Algeria-specific annual time series for the period between 1972 and 2021, with 50 observations per variable. The following mathematical expression represents the generic model:

$$CO_2 = f(GDP, \quad Engy, \quad DEN, \quad URB, \quad TRD)$$

The variables are explained as follows:

CO_2: Annual carbon dioxide emissions (per capita); this is the only dependent variable in this study.

GDP: Per capita gross domestic product (at constant prices in US dollars in 2015).

ENGY: Energy use (kilograms of oil equivalent per capita).

DENS: Annual population growth rate.

URB: Urban population growth (annual percentage).

TRD: Trade as a percentage of gross domestic products.

The formula for the model is given as follows:

$$CO_{2t} = \alpha + \beta_1 GDP + \beta_2 ENGY + \beta_3 DENS + \beta_4 URB + \beta_5 TRD + \varepsilon_t$$

Where t is the time period, α is the constant term, β is the elasticity coefficients, and ε represents the random error term. The selection of these variables was based on the foundations of the economic theory used in building standard models of many similar research topic.

4- RESULTS AND DISCUSSION

4.1- Statistics

The statistical characteristics of the variables analysed are displayed in Table 1(also see Figure 2 in appendix). The number of observations used in the model for each time series variable (CO_2, GDP, TRD, URB, DENS, and ENGY) was 50, corresponding to the years included in the model between 1972 and 2021. In addition, the highest and lowest values of the variables were as follows: 4.203332 and 1.958642 for the CO_2 variable; 4.246.244 and 2680.804 for the GDP variable; 1622.750 and 295.6879 for the ENGY variable; 4.815944 and 1.348867 for the DENS variable; 5.290481 and 2.371250 for the URB variable; and 76.68452 and 32.68452 for the TRD variable. It should be highlighted that the DENS variable had a lower probability value (0.016136) than the other study variables.

Table 1. Descriptive statistics of the study variables

Variables	CO_2	ENGY	GDP	TRD	URB	DENS
Mean	3.145804	919.0924	3431.688	58.17952	3.536880	2.282647
Median	3.198155	888.7332	3333.309	58.38583	2.922551	1.986240
Maximum	4.203332	1622.750	4246.244	76.68452	5.290481	4.815944
Minimum	1.958642	295.6879	2680.804	32.68458	2.371250	1.348867
Std. Dev.	0.585377	336.6997	468.8907	10.61337	1.009556	0.788665
Skewness	-0.177020	0.101968	0.277553	-0.249774	0.723277	0.962424
Kurtosis	2.427123	2.700634	1.775401	2.477505	1.891293	3.506534
Jarque-Bera	0.944860	0.273353	3.766220	1.088643	6.920308	8.253363
Probability	0.623485	0.872252	0.152116	0.580235	0.031425	0.016136
Sum	157.2902	45954.62	171584.4	2908.976	176.8440	114.1323
Sum Sq. Dev.	16.79066	5554967.	10773065	5519.533	49.94094	30.47760
Observations	50	50	50	50	50	50

Source: Prepared by researchers using an EViews 12 statistical program

4.2- Stationarity test

The study employed yearly data from 1972 to 2021.The statistical program EViews 12 was used to assess the stationarity of the time series for the variables examined, including CO_2, GDP, TRD, URB, DENS, and ENGY. The stability test of the time series was performed using Dickey-Fuller unit root testing. The same findings were achieved using the Philips Perron root test and the Augmented Dickey-Fuller (ADF) test (see Table 2 in appendix).

Initially, the order of variable integration was investigated to determine the presence of unit roots and the sequence of integration for all variables. The stationarity test was conducted initially in levels and then in the first difference.

At the stage of analysis, the ADF unit root test showed that the probability values of four variables were higher than 5%, which suggests that they are stable when a constant is present. The CO_2 variable was stable at 5%, while the DENS variable was steady at 1%. When examining the stability of the variables in the presence of both a constant and a trend, we identified three unstable variables and three stable variables (CO_2, URB, and DENS), at 1%. In the third scenario, all variables were unstable, and the study of stability without a constant or trend was also unstable. All probability values showed that the all-time series was stable at a 1% significance level after applying the first difference.

After studying the time series stability of the study variables CO_2, GDP, TRD, URB, DENS, and ENGY and confirming their stability in the first difference, the ARDL model was used to estimate the parameters of the variables in the short- and long-runs.

4.3- Testing the optimal lag length and estimation of ARDL Model

The appropriate amount of delay must be defined to determine the link between the independent variables GDP TRD, URB DENS, and ENGY and the dependent variable CO_2 using the Akaike information criterion(see Figure 3in the appendix).

Figure 3 shows that the best model representing the optimal lag periods is ARDL (2, 3, 4, 1, 0, 3), thereby adopted by this study. It should be noted that when estimating the ARDL model, the statistical software EViews 12 automatically determines the best lag times.

The data presented in Table 3 in the appendix indicate the significance of the estimated model through the R-squared value of 0.91, indicating that the variables have a 91% effect on variations in CO_2. The F-statistic equalled 15.82 with a probability value of Prob(F-statistic)=0, which means that the explanatory variables are not spurious, indicating the significance of the studied model as a whole.

4.4- ARDL Bounds Test

The Bounds Test determines if the variables in the ARDL model have a cointegration correlation. Under the null hypothesis of no cointegration, if the estimated F-statistic is less than the lower critical value, it suggests no cointegration. However, if it is more than the upper critical value, it shows that a cointegration correlation exists (Pesaran et al., 2001).The results of the Bounds Test for cointegration using the ARDL model are displayed in Table 4.

The null hypothesis is rejected in favour of the alternative hypothesis at significance levels of 10%, 5%, 2.5%, and 1% since the estimated F-statistic exceeded the upper critical values. These results demonstrate a long-run equilibrium between the variables under consideration.

Table 4. Results of Bounds Test for Cointegration.

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
		Asymptotic: n=1000		
F-statistic	12.27067	10%	2.08	3
K	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15

Source: Prepared by researchers using an EViews 12 statistical program

4.5-Short-run and long-run equilibrium:

From Table 5 below, we obtain the results of the short-run relationship. The error correction coefficient reached CointEq(-1) = -1.165 at a significant level of less than 1%, which confirms the existence of a long-run equilibrium relationship between the independent variables and the dependent variable CO_2. About 116.5% of the short-run imbalances in CO_2 in the period t-1 can be corrected in the current period t to rebalance in the long-run in the event of any changes in the independent variables represented by GDP TRD, URB DENS and ENGY.

Table 5. Short-run coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO2(-1))	0.277443	0.096643	2.870814	0.0079
D(DENS)	-0.891860	0.419992	-2.123516	0.0430
D(ENGY)	-0.002601	0.000838	-3.105368	0.0044
D(GDP)	0.001312	0.000343	3.825954	0.0007
D(URB)	1.573540	0.449090	3.503844	0.0016
CointEq(-1)*	-1.165227	0.113724	-10.24609	0.0000

Source: Prepared by researchers using an EViews 12 statistical program

In terms of long-run equilibrium, as shown in Table 6, the variable TRD had an elasticity of -0.01, showing an inverse correlation with CO_2 emissions. The other variables had positive values. The predicted parameter findings using the probability and t values show that the DENS and URB variables lacked statistical significance and had no remarkable long-run influence on CO_2 emissions. However, the factors GDP, ENGY, and TRD were statistically significant.

Table 6- Results of ARDL Error Correction Regression

Levels Equation Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
DENS	0.058910	0.339966	0.173283	0.8637
ENGY	0.001739	0.000562	3.093379	0.0046
GDP	0.000508	0.000190	2.670890	0.0127
TRD	-0.019185	0.006295	-3.047883	0.0051
URB	0.109786	0.310393	0.353700	0.7263
C	0.651329	0.832252	0.782610	0.4407
EC = CO2 - (0.0589*DENS + 0.0017*ENGY + 0.0005*GDP -0.0192*TRD + 0.1098*URB + 0.6513)				

Source: Prepared by researchers using an EViews 12 statistical program

4.6- Model quality tests

To ensure the model is of high quality and free from common flaws, the following standardized tests were performed:

4.6.1. Test for the normal distribution of residuals

The Jarque-Bera test value examined the residuals' probability distribution normality. The calculated value for this test was 1.71 at a significance level of 0.42, which is more than the significance level of

5%. We thus accept the null hypothesis indicating that residuals conform to a normal distribution (see Figure 4 in the appendix).

4.6.2. Breusch-Godfrey Serial Correlation LM test

Table 7 presents the outcomes of the Breusch-Godfrey Serial Correlation LM test, which indicates that the F-statistic value attained 0.08 with an estimated probability value of 0.92, exceeding the significance threshold of 5%. Wethus accept the null hypothesis, which says residuals do not display autocorrelation in the estimated model.

Table 7. Breusch-Godfrey Serial Correlation LM test results

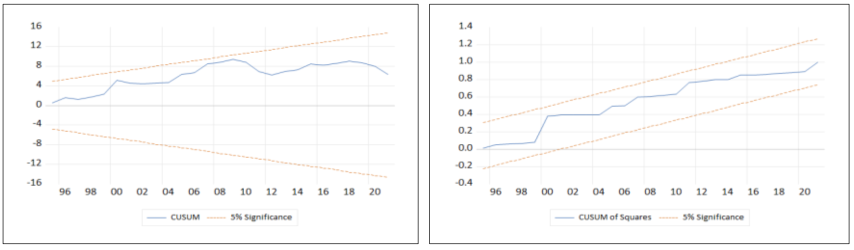
Breusch-Godfrey Serial Correlation LM Test:			
Null hypothesis: No serial correlation at up to 2 lags			
F-statistic	0.082746	Prob. F(2,25)	0.9208
Obs*R-squared	0.302501	Prob. Chi-Square(2)	0.8596

Source: Prepared by researchers using an EViews 12 statistical program

3.6.3 Structural stability test

This result was obtained by executing a Cusum&Cusum of Squares test. As shown in the two figures below, the statistical curves did not surpass the confidence interval bounds at the 5% significance level. The model is, therefore, structurally stable, which validates the relevance of the study's correlation, namely the short-run and long-run stability parameters of the ARDL model.

Figure 5. Cusum and Cusum of Squares test results



Source: Prepared by researchers using an EViews 12 statistical program

CONCLUSION

The problem of climate change currently affects all the world's countries in varying proportions. However, the historical responsibility for this phenomenon is mainly related to the industrial revolution in the industrialized countries, which has caused land pollution and significant changes in the climate. This has caused the third-world countries to face adaptation and resilience challenges despite the lack of its financial resources and technical expertise.

In order to answer the problem of the study, we built a standard model to demonstrate the impact of economic growth, international trade, energy depletion, population growth rate, and urban population growth on the proportion of damage caused by CO_2 emissions as an indicator of environmental degradation in Algeria during 1972-2021 by applying the ARDL model. The stability of all variables was achieved in the first difference: "After studying the stability of time series of study variables by the ARDL model, from which the results of the Bounds Test joint integration boundary test showed a long-run balanced relationship, and after estimating the model and examining its quality by conducting the natural distribution test of the protectors, Breusch-Godfrey Serial Correlation LM Test and Cusum and Cusum of Squares Test for Model Structuring Stability model". It was found that this model is statistically good and demonstrates a long-run balance between study variables.

GDP, URB, DENS, and ENGY were found to be positively correlated with the damage caused by CO_2 emissions representing environmental degradation. Our econometric study validated the hypothesis that continuing Algeria's economic approach based on excessive combustion and a lack of ecological consideration results in a higher rate of environmental damage and increased emissions of climate-inducing greenhouse gases.

In the light of what has been achieved through the econometric study and the compulsory imperative to link and coordinate economic and environmental life, and with increasing environmental pressures on economic well-being "Algeria, as a developing country, had an obligation to achieve economic growth that guarantees the needs of its present and future generations by including the environmental aspect in the formulation of various economic policies.This can be achieved by changing all traditional concepts and creating a positive cooperative system between the economy and the environment through the adoption of the concept of environmentally sustainable economic activity. This could transform the perception of being a negative influencer to a supporter through the collective efforts of both the private sector, public and community-based institutions by adopting projects, creating innovations and pursuing rigorous and stimulating policies and strategies to preserve the environment on short and long terms.

Future research can be conducted on a regional and a state level to locate the area most affected by climate change and how they relate to CO_2 emissions. More variables not mentioned in this study or using different standard methods can be included.

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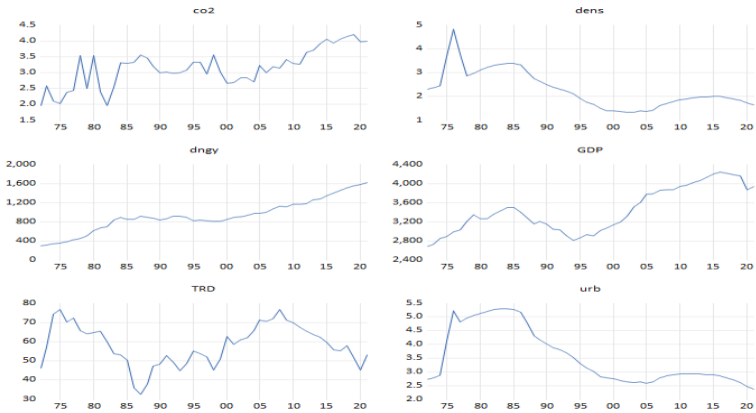
Appendix

Figure 1. Graphical illustration of the variables



Source: Prepared by researchers using an EViews 12 statistical program

Table 1. Unit Root Test ADF

	With Constant		With Constant & Trend		Without Constant & Trend	
CO2	-2.9275	**	-4.2835	***	0.1890	n0
ENGY	0.2162	n0	-0.7702	n0	4.6234	n0
GDP	-1.3018	n0	-1.6633	n0	1.0738	n0
TRD	-2.0553	n0	-1.9862	n0	-0.1883	n0
URB	-1.3424	n0	-6.1503	***	-0.5222	n0
DENS	-4.3800	***	-5.4588	***	-0.8361	n0
d(CO2)	-10.8870	***	-10.7622	***	-10.8882	***
d(ENGY)	-4.9591	***	-4.9216	***	-3.7022	***
d(GDP)	-4.5594	***	-4.5289	***	-4.3523	***
d(TRD)	-5.4406	***	-5.3139	***	-5.4985	***
d(URB)	-4.3038	***	-4.4740	***	-4.3464	***
d(DENS)	-4.9890	***	-4.9477	***	-5.0340	***

Notes: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1%. and (no) Not Significant *MacKinnon (1996) one-sided p-values.

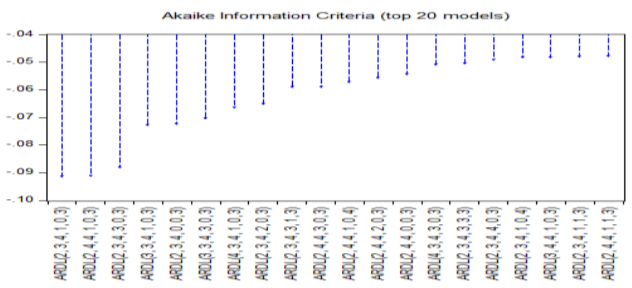
Source: Prepared by researchers using an EViews 12 statistical program

Table 2. ARDL model output

Sample (adjusted): 1976 2021			
Included observations: 46 after adjustments			
Maximum dependent lags: 4 (Automatic selection)			
Model selection method: Akaike info criterion (AIC)			
Dynamic regressors (4 lags, automatic): DENS ENGY GDP TRD URB			
Fixed regressors: C			
Number of models evalulated: 12500			
Selected Model: ARDL(2, 3, 4, 1, 0, 3)			
R-squared	0.913420	Mean dependent var	3.230466
Adjusted R-squared	0.855699	S.D. dependent var	0.525524
F-statistic	15.82496	Durbin-Watson stat	2.062215
Prob(F-statistic)	0.000000		

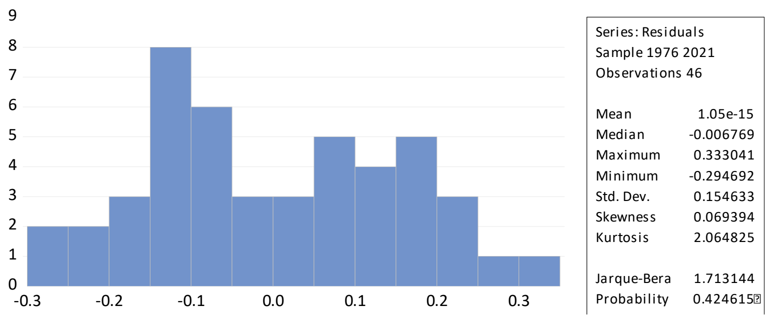
Source: Prepared by researchers using an EViews 12 statistical program

Figure 2. Akaike information criteria test



Source: Prepared by researchers using an EViews 12 statistical program

Figure 3. Results of the normal distribution test for the residuals



Source: Prepared by researchers using an EViews 12 statistical program