Economic determinants of per capita carbon dioxide emissions An econometric comparative study between Algeria and the United States of America during the period (1990-2022).

Merwan Haid [1]*.

[1]Lecturer Professor A, khemis miliana university, (Algeria)
✉ m.haid@univ-dbkm.dz
https://orcid.org/0009-0003-7103-1365

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* ***Corresponding Author***

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Abstract

There is no doubt that estimating the equation of carbon dioxide emissions per capita in Algeria and comparing it with one of the largest countries causing these emissions helps a lot in avoiding the negative environmental waste resulting from it. Therefore, comparative standard studies continuously occupy a special space, and impose themselves as an important scientific branch, given the considerable role played by the power values of this dangerous gaseous substance, like other environmental, economic and social phenomena, in drawing and directing ideal programs and policies.

Through this study, we will try to narrate the reality of carbon dioxide emissions and compare the individual's share of carbon dioxide emissions between Algeria and the United States by taking the past of this phenomenon as a basis for estimating its equation in terms of some economic variables according to the literature of the study using the Autoregressive Distributed Lag (ARDL) model.

Keywords: per capita CO2 emissions, CO2 emissions, ARDL model.

JEL classification codes: E22 ، C35

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المحددات الاقتصادية لنصيب الفرد من انبعاثات ثاني أكسيد الكربون دراسة قياسية مقارنة بين الجزائر والولايات المتحدة الامريكية خلال الفترة (1990-2022).

مروان حايد [1] *

[1] أستاذ محاضر أ، جامعة خميس مليانة، (الجزائر)

✉ m.haid@univ-dbkm.dz

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الملخص:

لا شك أن تقدير معادلة مستوى نصيب الفرد من انبعاثات غاز ثاني أكسيد الكربون في الجزائر ومقارنته من أحد أكبر الدول المسببة لهذه الانبعاثات تساعد كثيرا على تفادي وتجنب المخلفات البيئة السلبية الناتجة عنها، لذلك أصبحت الدراسات القياسية المقارنة تشغل باستمرار حيزا خاصا، وتفرض نفسها كفرع علمي هام، نظرا للدور المعتبر الذي تلعبه القيم القدرة لهذه المادة الغازية الخطيرة، على غرار غيرها من الظواهر البيئية والاقتصادية والاجتماعية الأخرى، في رسم وتوجيه البرامج والسياسات المثالية.

سنحاول من خلال دراستنا هذه، سرد واقع انبعاثات غاز ثاني أكسيد الكربون ومقارنة نصيب الفرد من انبعاثات غاز ثاني أكسيد الكربون بين الجزائر والولايات المتحدة الامريكية بأخذ ماضي هذه الظاهرة كأساس لتقدير معادلتها بدلالة بعض المتغيرات الاقتصادية حسب ادبيات الدراسة باستخدام نموذج الانحدار الذاتي للفجوات الزمنية الموزعة المتباطئة ARDL

الكلمات المفتاحية: نصيب الفرد من انبعاثات (CO2)، انبعاثات (CO2)، نموذج ARDL.

تصنيف JEL: C35 ،E22

I- Introduction

Carbon dioxide, known for its harmful effects on the natural environment, is mainly produced through the combustion of organic materials and fermentation processes, and is also a by-product of various chemical industries. This compound is best known for its contribution to global warming, causing the Earth's temperature to rise. In recent years, carbon dioxide has received great attention as a potential alternative to environmentally harmful organic solvents in various industries. However, it is now widely recognized that it is harmful to the environment and human health, as studies have revealed that increased carbon dioxide emissions resulting from the burning of fossil fuels , including oil and gas, pose a threat to the thermosphere, the outer layer of the atmosphere, leading to its contraction.

Environmental issues and challenges resulting from climate change have become at the top of the global dialogue agenda, as evidence is increasing that human activity is the main reason behind the major environmental changes that the Earth is witnessing, and among the most prominent factors causing this change is the emission of carbon dioxide, resulting from industrial activities and burning Fossil fuels, which are considered one of the most harmful air pollutants affecting the environment and human health. Understanding the factors that determine the amount of carbon dioxide emissions produced by each individual is vital for developing effective strategies to combat climate change, and from here the role of economics in shaping this landscape is highlighted, as various economic decisions are linked to the level of emissions resulting from production, consumption, and the global distribution of wealth, including The economic determinants of per capita carbon dioxide emissions are among the factors that form the main basis for analyzing environmental sustainability and economic growth, including population growth, consumption rates, the structure of the economy, and the energy and environmental policies adopted by governments.

In this context, it is important to understand the impact of economic factors on per capita carbon dioxide emissions in identifying effective policies and measures that can be taken to reduce these emissions and promote environmental sustainability and economic growth. Based on the above and the concerns mentioned above, the problem of this research can be formulated in the following main question:

What are the economic determinants of per capita carbon dioxide emissions in Algeria and the United States of America?

❖ **Research objectives:**

✓ Identify the reality of carbon dioxide emissions in Algeria and the United States of America.

✓ Estimating the equation of per capita carbon dioxide emissions in terms of some economic variables using the ARDL model.

✓ Comparing the results of the standard study between Algeria and the United States of America.

❖ **Research Methodology and Tools Used:**

✓ The research relies on three tools for the descriptive analytical approach:

✓ Theoretical Study: This involves desk research and review of various Arabic and foreign references, sources, conferences, scientific theses, journals, and internet sites related to the topic.

✓ Comparative Analysis of Carbon Dioxide Emissions: This entails examining the developments in carbon dioxide emissions, along with the factors affecting them, based on data provided by the World Bank during the period from 1990 to 2022.

✓ Statistical Analysis Using Econometric Techniques: This involves estimating the individual's share equation of carbon dioxide emissions in relation to economic variables using the ARDL model and "eviews" software.

II. Carbon dioxide emissions in Algeria and the United States.

Carbon dioxide, or CO2, is a chemical compound and one of the components of the atmosphere, consisting of a carbon atom bonded to two oxygen atoms. It exists as a gas in its natural state but is also used in its solid state, commonly known as dry ice. It plays a crucial role in the carbon cycle in nature and is a vital element in the process of photosynthesis in plants, where, in the presence of light, atmospheric CO2 absorbs reflected radiation from the Earth's surface, re-emitting it back as thermal energy, effectively acting as a blanket. Climate scientists currently believe that an increase in the concentration of atmospheric CO2 enhances this blanket effect, leading to global temperature rise. Additionally, accumulated CO2 in the atmosphere causes significant damage to Earth's ecosystem. (مصطفى، 2021)

II – 1 Carbon Dioxide Emissions and the Phenomenon of Global Warming: Heating the Earth's surface by the sun relies on 71% of the solar energy reaching it, absorbed by the atmosphere and the surface, while 29% is reflected back into space, (Scott Denning, a professor of atmospheric science at Colorado State University), stated in this context that we need Earth's atmosphere to act like a blanket trapping some heat. This "blanket" is composed of several gases known as greenhouse gases, as they retain heat, much like the glass panels of a greenhouse trap solar heat (Denning, 2019), Denning also mentioned that the greenhouse effect is a natural process; without it, the Earth would be just a frozen white ball hanging in space, uninhabitable. However, this natural process has begun to change due to human activities that enhance the greenhouse effect, leading to climate change. Most of this change is attributed to carbon dioxide emissions from burning fossil fuels (coal, oil, and natural gas). The largest sources of carbon dioxide emissions in the world include China, the United States, and its major oil and industrial companies, Human-caused emissions have increased atmospheric carbon dioxide levels by about 50% since pre-industrial levels, The consequences of global warming include (J.bush, 2018) :

- ❖ **Fluctuations in Temperature**: Temperature varies unevenly across the Earth's surface, with the rate at which air temperature rises above land surpassing the rate of increase over oceans. This results in the greatest temperature rise occurring in the North Pole. Consequently, there will be a decrease in the extent of snow and ice coverage on both land and sea, intensifying the impact of warming. It's worth noting that the Arctic is experiencing temperature rise at a rate twice as fast as the rest of the world**.**
- ❖ **Changes in rainfall patterns**: There is a clear relationship between the phenomenon of global warming and changes in rainfall patterns worldwide. Certain regions, such as polar and sub-polar areas, have experienced an abnormal increase in heavy rainfall, while mid-latitude regions have witnessed a decrease. Expected changes include increased rainfall near the equator and decreased rainfall in semi-equatorial regions, ultimately leading to increased likelihood of weather fluctuations in these areas. With rising temperatures, evaporation rates will increase, resulting in reduced summer rainfall in North America, Europe, and Africa. Consequently, some areas will suffer from drought, while others will face significant flooding due to heavy rainfall**.**
- ❖ **Tropical Cyclones**: Scientists have documented a rise in temperatures in the Atlantic Ocean region and an increase in the intensity of hurricanes there since the 1970s. These findings indicate that the phenomenon of global warming is linked to Atlantic hurricanes, and scientists expect that the rise in temperature of tropical oceans will lead to an increase in hurricane strength worldwide in the next century**.**
- ❖ **Environmental Impact**: Global warming affects ecosystems and biodiversity of plants, animals, and other living organisms. Organisms typically diversify in different regions by adapting to their environments, including long-term climate patterns and sudden temperature changes caused by global warming. These temperature changes can negatively impact the habitats of living organisms. Some plants and animals have already shifted their habitats to accommodate higher temperatures. For example, biologists have documented certain species of butterflies and birds in the northern hemisphere migrating northward to avoid rising temperatures. Climate change also affects biological processes in some organisms. For instance, trees begin to leaf or flower earlier in the spring, and some mammals end their hibernation early. Additionally, rising temperatures affect seasonal migration patterns of birds, fish, and other animals**.**

II –2 Ranking of countries according to their contribution to carbon dioxide emissions in the world: China ranks first globally in carbon emissions with about 12 million tons per year, accounting for 32.88% in 2022, where it was second in 2006, due to industrial growth witnessed in the last 20 years. Behind China is the United States, which causes approximately 7 million tons of emissions (CO2), which reduced to 4 million tons in 2022 due to the efforts of the American government in technological development to preserve the environment and reduce carbon dioxide emissions. Following them is India with emissions reaching 2.693 million tons annually, accounting for 6.91%.

Also, two Middle Eastern countries ranked in the top fifteen, Iran and Saudi Arabia. Iran ranked seventh with carbon emissions exceeding 1 million tons, accounting for 2.80%, while Saudi Arabia ranked tenth globally.

Saudi Arabia topped the Arab countries with 1.57% globally, with about 607 thousand tons of carbon dioxide per year, followed by Egypt ranking 25th globally with emissions reaching 265 thousand tons and a percentage of 0.69% of global production. The total percentage of Arab countries' production of carbon dioxide emissions reaches 8.5% globally.

Below is the ranking of the top 5 Arab countries in terms of their annual contribution percentage globally to CO2 emissions measured in metric tons in 2022:

1. Saudi Arabia: 1.57%
2. Egypt: 0.69%
3. United Arab Emirates: 0.56%
4. Iraq: 0.50%
5. Algeria: 0.46%

Table N°1

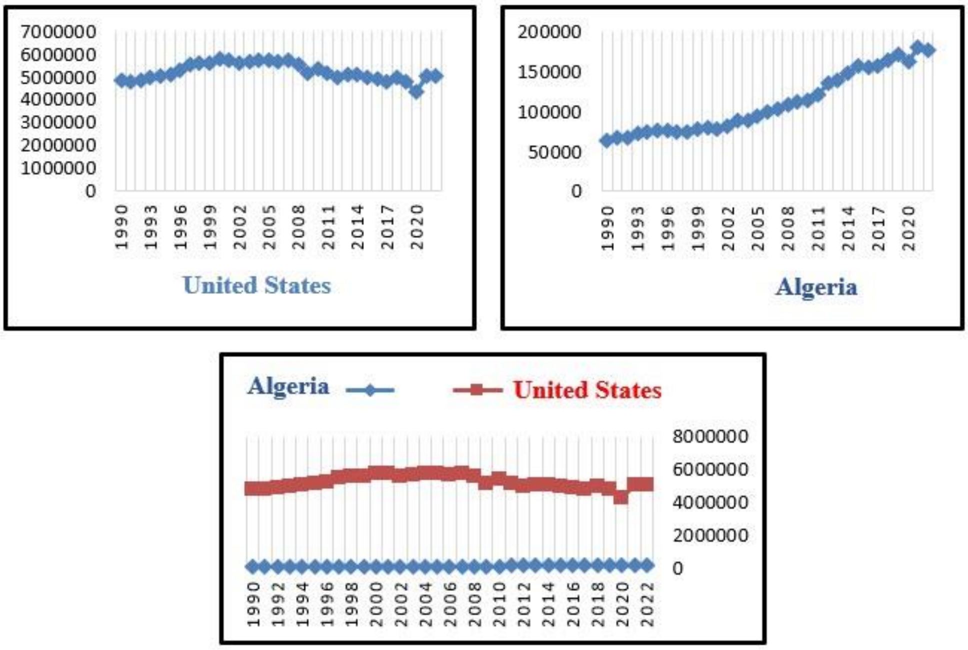
Ranking of countries for carbon dioxide emissions in 2006-2022

Ranking 2006				**Ranking 2022**			
Ranking	**countries**	**Volume (1000 tons)**	**%**	**Ranking**	**countries**	**Volume (1000 tons)**	**%**
1	United States	7,031,916	22.2 %	1	China	12,667,428.	32.88%
2	China	5,461,014	18.4 %	2	United States	4,853,780.	12.60%
3	Russia	1,708,653	5.6 %	3	India	2,693,034.	6.991%
4	India	1,742,698	4.9 %	4	Russia	1,909,039.3	4.956%
5	Japan	1,208,163	4.6 %	5	Japan	1,082,645.4	2.810%
6	Germany	786,660	3.0 %	6	Indonesia	692,236.1	1.797%
7	Canada	544,091	2.3 %	7	Iran	686,415.7	1.782%
8	United Kingdom	522,856	2.2 %	8	Germany	673,595.3	1.749%
9	South Korea	509,170	1.7 %	9	South Korea	635,503.0	1.650%
10	Italy	449,948	1.7 %	10	Saudi Arabia	607,907.5	1.578%
11	Mexico	475,834	1.6 %	11	Canada	582,072.9	1.511%
12	South Africa	435,878	1.6 %	12	Mexico	487,774.0	1.266%
13	Iran	538,404	1.6 %	13	Turkey	481,247.5	1.249%
14	Indonesia	378,250	1.4 %	14	Brazil	466,770.4	1.212%
15	France	373,693	1.4 %	15	South Africa	404,974.5	1.051%
16	Brazil	331,795	1.2 %	16	Australia	393,162.5	1.021%
17	Spain	330,497	1.2 %	17	United Kingdom	340,610.3	0.884%
18	Ukraine	330,039	1.2 %	18	Vietnam	327,905.6	0.851%
19	Australia	326,757	1.2 %	19	Italy	322,948.7	0.838%
20	Saudi Arabia	308,393	1.1 %	20	Poland	321,954.0	0.836%
21	Poland	307,238	1.1 %	21	France	315,299.5	0.818%
22	Thailand	268,082	1.0 %	22	Thailand	282,445.8	0.733%
23	Turkey	226,125	0.8 %	23	Malaysia	277,531.8	0.720%
24	Kazakhstan	200,278	0.7 %	24	Taiwan	275,574.0	0.715%
25	Algeria	194,001	0.7 %	25	Egypt	265,961.3	0.690%
26	Malaysia	177,584	0.7 %	26	Spain	254,363.4	0.660%
27	Venezuela	172,623	0.6 %	27	Kazakhstan	245,886.3	0.638%
28	Egypt	158,237	0.6 %	28	United Arab Emirates	218,799.3	0.568%
29	United Arab Emirates	149,188	0.5 %	29	Pakistan	199,329.9	0.517%
30	Netherlands	142,061	0.5 %	30	Iraq	193,836.3	0.503%
31	Argentina	141,786	0.5 %	31	Argentina	184,037.2	0.478%
32	Uzbekistan	137,907	0.5 %	32	Algeria	177,079.4	0.460%
33	Pakistan	125,669	0.5 %	33	Philippines	155,380.9	0.403%
34	Czech Republic	116,991	0.4 %	34	Netherlands	134,663.6	0.350%
35	Nigeria	114,025	0.4 %	35	Ukraine	132,541.5	0.344%
36	Belgium	100,716	0.4 %	36	Uzbekistan	132,433.5	0.344%

Source: Prepared by the researcher based on data from the Wordometer website www.worldometers.info

II - 3 Evolution of Carbon Dioxide Emissions in Algeria and the United States: From Figure (1) depicting the evolution of carbon dioxide emissions in Algeria and the United States during the period (1990-2020), it is noticeable that the United States exerted more control over the curve, whereas Algeria's curve shows a continuous increase at the same rate and direction. There is a spike in both curves in the years (2020-2021-2022) due to the hole imposed by the COVID-19 pandemic. When plotting both curves on the same graph, it becomes apparent that the recorded numbers in Algeria could be negligibly small compared to the United States. This is a natural consequence of the difference in area and the vast disparity in population and industrial growth rate between Algeria and the United States. Therefore, it is not logical to directly compare the volume of carbon dioxide emissions between Algeria and the United States. Hence, in our study, we will rely on a more expressive variable for comparison, which is the average per capita carbon dioxide emissions in metric tons in Algeria and the United States, and attempt to model it by indicating some macroeconomic variables**.**

Figure N° 1
Evolution of Carbon Dioxide Emissions in Algeria and the United States.



Source: Prepared by the researcher based on World Bank data

II-4 Evolution of per capita carbon dioxide emissions in Algeria and the United States (metric tons): Observing from figures (2) and (3), the evolution and rate of change in the average per capita carbon dioxide emissions in Algeria and the United States can be noted. The evolution of these rates is distinguished as follows:

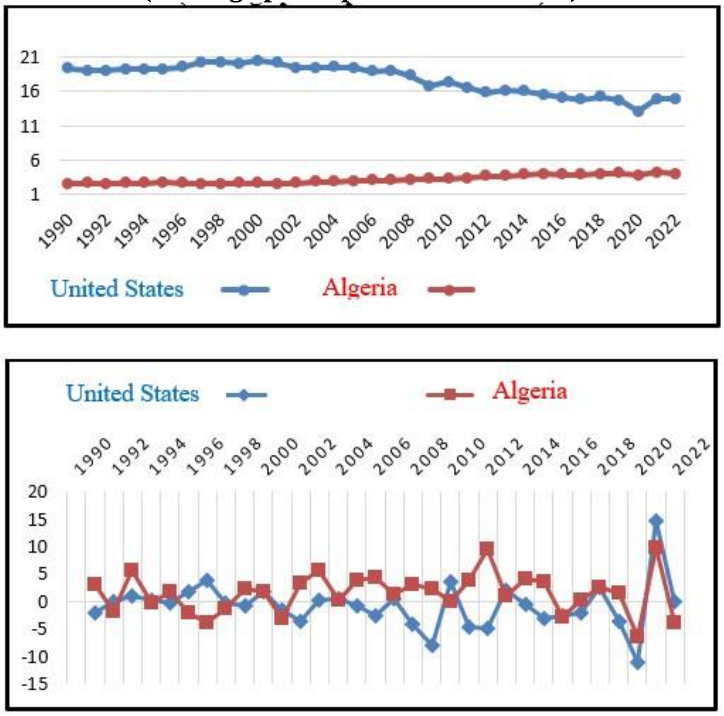
From 1990 to 2007, the per capita carbon dioxide emissions in the United States were significantly high, exceeding 19 metric tons per capita. Since then, the United States has gradually reduced its emissions, reaching around 14.8 metric tons per capita in 2017. This reduction can be attributed to the adoption of more sustainable practices and improvements in energy efficiency, in addition to a shift towards renewable energy sources.

In Algeria, carbon dioxide emissions have been much lower than in the United States over the years, but they have witnessed a gradual increase in the early period. They rose from approximately 2.4 metric tons per capita in 1990 to about 4 metric tons per capita in 2021. This increase is attributed to economic growth and reliance on fossil energy sources.

As a result of the above, it is noticeable from figure (3) that the points of the curve representing the evolution of per capita carbon dioxide emissions in Algeria are mostly positive (above zero), contrary to the points of the curve representing the evolution of per capita carbon dioxide emissions in the United States, which are mostly negative (below zero).

Figure N° 2

Evolution and growth rates of carbon dioxide emissions in Algeria and the United States of America (Average per capita in metric tons)



Source: Prepared by the researcher based on World Bank data

III. Autoregressive distributed lag (ARDL) model.

The Autoregressive Distributed Lag (ARDL) model, developed by Shinand and Sun in 1998, along with Pesaran in 1997, integrates autoregressive models with distributed lag models into a single framework. In this methodology, time series are functions of their own lagged values as well as the current and lagged values of explanatory variables over one or more periods.

III-1 Features and General form of the ARDL Model: the ARDL model boasts several advantages, including (Shorbagy, 2009):

- The ARDL model does not require the time series to be integrated of the same order, either I(0) or I(1), as long as they are not integrated of order I(2) only.
- It allows for the estimation of both long and short-term effects simultaneously, along with the capability to handle explanatory variables in the model with different lag lengths.
- The results obtained from its application are accurate even with small sample sizes, owing to the simplicity of estimating cointegration using the ordinary least squares method (Frimpong, J. & Oteng-Abayie., 2006).
- It distinguishes between dependent and explanatory variables in the model, enabling the testing of relationships between the original variables (in levels) regardless of whether the explanatory variables are I(0), I(1), or a mixture of both.
- Utilizing this model helps overcome issues related to variable deletion and autocorrelation problems, resulting in efficient and unbiased estimates.
- The ARDL model incorporates a sufficient number of lagged time periods to obtain the best dataset from the overall framework.
- It provides superior parameter estimates for the long term, with diagnostic tests being highly reliable

❖ Through the ARDL model, the cointegrative relationship between the dependent variable and independent variables can be identified, along with determining the impact of each independent variable on the dependent variable. Its estimated parameters for both short and long terms are more consistent compared to other methods of testing cointegration.

The general form of the model consists of a dependent variable (Y) and (n) explanatory variables (X1, X2 ... Xn) and (m) lags, written as follows: (ARDL) (p, q1, q2 ... qK)

$$\Delta Y_t = c + B_1 Y_{t-1} + B_2 X_{1t-1} + B_3 X_{2t-1} + \ldots\ldots + B_{k+1} X_{kt-1} + \sum_{i=1}^{p-1} \lambda_{1i}\, \Delta Y_{t-i} + \sum_{i=0}^{q_1-1} \lambda_{2i}\, \Delta X_{1t-i}$$

$$+ \sum_{i=0}^{q_2-1} \lambda_{3i}\, \Delta X_{2t-i} + \ldots\ldots + \sum_{i=0}^{q_k-1} \lambda_{(k+1)i}\, \Delta X_{kt-i} + \mu_t \quad \ldots\ldots\ldots (1)$$

Long-run equation

Short-run equation

Where:

α: Initial differences/constant term.

μt: Random error limit.

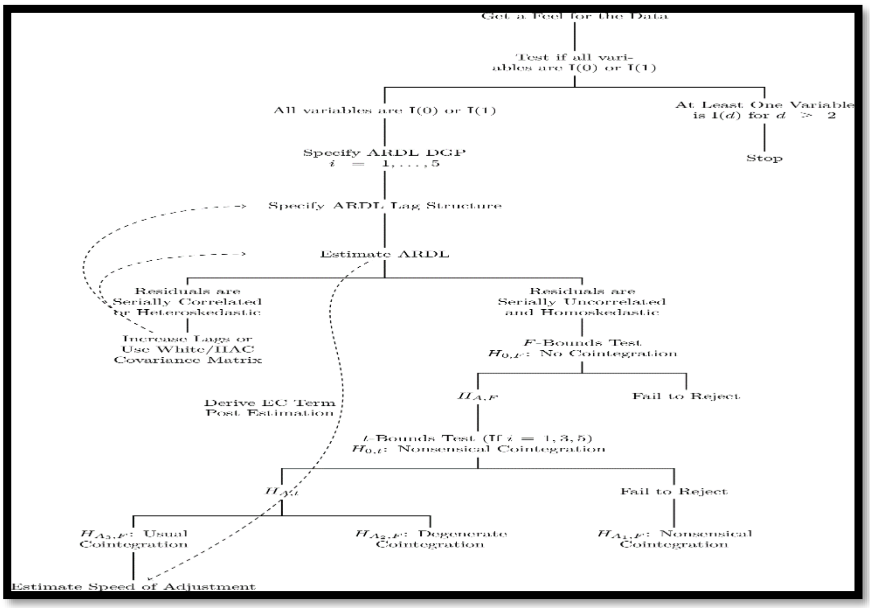
B: Long-term relationship coefficients.

λ: Short-term relationship coefficients.

(p, q1, q2, ... qK): Represent the lags for variables (Y, X1, X2, ... XK) respectively.

III-1 The Steps of Cointegration Analysis within the ARDL Model: to apply the cointegration analysis methodology within the ARDL model framework using the bounds test, it is necessary to follow a series of steps summarized as follows**:**

Figure N° 3
The Steps of Cointegration Analysis within the ARDL Mod



Source:http://blog.eviews.com/2017/05/autoregressive-distributed-lag-ardl.html; seen at 21/03/2021 10:25 AM.

III -3 The Unit Root Test: In a study conducted by (Nelson, & Plosser, 1982)it was found that most macroeconomic variables are not stationary at the I(0) level. This makes the use of Ordinary Least Squares (OLS) method inappropriate, as it can yield high values for both (T,F) statistics and the coefficient of determination (R^2).

To avoid the issue of spurious regression, which may not provide meaningful insights or economic interpretations, the first step in data analysis is testing for the stationarity of time series: (Dickey, D. & Fuller, W., 1979)

A time series Xt is said to be stationary when:

- ✓ Its mean is constant, i.e., E(Xt) = constant for all t
- ✓ Its variance is constant, i.e., Var(Xt) = constant for all t
- ✓ Its covariance depends on time, i.e., Cov(Xt, Xt+k) = depends on t & k≠0

This means that both its mean and variance remain constant over time, while the covariance between any two values of the variable X depends on the time difference between these two values.

We will employ the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test, which examine the hypothesis of a unit root and consequently the non-stationarity of the time series.

III - 4 Optimal Lag Length Testing: The optimal lag lengths for the first differences of variable values in Equation (1) are tested using the unrestricted vector autoregression model. There are five criteria for determining the lag length, as follows (غزغازي م.، 2022):

- ✓ Final Prediction Error (FPE, 1969) criterion, given by the formula:

$$\mathrm{FPE}_{(\mathrm{P})} = \left[\frac{\mathrm{T+P-k}}{\mathrm{k-p.k}}\right]^{\mathrm{k}} .\det \sum \mathrm{e} \;\ldots\ldots\ldots.(4)$$

- ✓ Akaike Information Criterion (AIC, 1973) criterion, given by the formula:

$$\mathrm{AIC}_{(\mathrm{P})} = \mathrm{Ln}\left[det\left(\sum e\right)\right] + \frac{2\mathrm{k}^2 P}{T} \;\ldots\ldots\ldots\; (5)$$

- ✓ Schwarz Criterion (SC, 1978) criterion, given by the formula:

$$\mathrm{SC}_{(\mathrm{P})} = \mathrm{Ln}\left[det\left(\sum e\right)\right] + \frac{2\mathrm{k}^2 P\; Ln\;(T)}{T} \;\ldots\ldots\ldots\; (6)$$

- ✓ Hannan & Quinn Criterion (H.Q, 1979) criterion, given by the formula:

$$\mathrm{H.Q}_{(\mathrm{P})} = \mathrm{Ln}\left[det\left(\sum e\right)\right] + \frac{2\mathrm{k}^2 P_c\; Ln.Ln\;(T)}{T} \;\ldots\ldots\ldots\; (7)$$

- ✓ Likelihood Ratio Test.

Where:

k: Number of variables in the model.

T: Number of observations.

P: Number of lag periods.

C: Represents an index for the strength of the criterion.

∑e: Matrix of estimated covariance and residual variance of the model.

All these tests agree that the optimal lag length (P) is the one that yields the lowest value for most criteria during testing.

III-5 Model Estimation: Before ensuring the existence of a long-term equilibrium relationship between the dependent variable and explanatory variables, Autoregressive Distributed Lag (ARDL) model parameters are estimated for both short and long terms, along with Error Correction Model (ECM) parameter. Ordinary Least Squares (OLS) method is utilized based on the specified lag lengths, and to determine the appropriate model, reliance is placed on Hendry's method which moves from general to specific, involving the elimination of first-order difference variables for any variable where the absolute values of its corresponding t-statistics are insignificantly less than one (Tang, 2022).

III - 6 Diagnostic Tests: Before adopting and implementing the previously estimated model, it is essential to ensure the quality of its performance. This is achieved through conducting the following diagnostic tests (Ghazghazi, 2022, p. 148):

- ✓ Lagrange Multiplier Test of Residual {Brush-Godfrey} (BG)
- ✓ Autoregressive Conditional Heteroscedasticity (ARCH)

- ✓ Jarque Bera (JB) test for normal distribution of random errors
- ✓ Ramsey (RESET) test for assessing the adequacy of model specification
- ✓ Multicollinearity Test for detecting linear dependence among independent variables

III -7 Cointegration testing according to the Bounds Testing Approach: According to Pesaran, the Bounds Testing Approach within the framework of ARDL can be applied regardless of the characteristics of the time series, whether they are stationary at their levels, integrated of the first order, or a combination of both. The only condition for applying this test is that the time series should not be integrated of the second order. Pesaran's method exhibits better properties in the case of short time series compared to other conventional methods in testing for cointegration (Pesaran, M. H & Shin, y., 1995).

To test the extent of the cointegrating relationship between variables in the framework of the UCEM model, Pesaran et al. (2001) introduce a modern method for testing the extent of the equilibrium relationship between variables under the unrestricted error correction model. This method is known as the Bounds Testing Approach and is conducted using either a Wald test or an F-statistic, which has a non-standard distribution and does not rely on factors such as sample size or including a trend variable in the estimation. The F-statistic is calculated according to the following formula (Francis, & Diebold., 2017):

$$\mathrm{F} = \frac{(\mathrm{SSR}_{res} - \mathrm{SSR})/\mathrm{M}}{\mathrm{SSR}/(\mathrm{n}-\mathrm{k})} \quad \ldots\ldots\ldots\ldots\ldots \quad (6)$$

Where:

SSRres: Sum of squared residuals for the constrained model (null hypothesis), indicating no long-term equilibrium relationship between the variables (no cointegration).

SSR: Sum of squared residuals for the unconstrained model (alternative hypothesis), indicating the presence of a long-term equilibrium relationship between the variables (cointegration).

M: Number of parameters in the constrained model.

n: Number of observations (sample size).

k: Number of variables.

After calculating the F-statistic, it is compared to the critical value of F tabulated by Pesaran et al. (2001). Since the F-test has a non-standard distribution, there are two critical values:

- ✓ Lower bound value: Assumes all variables are stationary at their original levels, i.e., integrated of order zero I(0)
- ✓ Upper bound value: Assumes all variables are stationary at their first differences, i.e., integrated of order one I(1).

And the decision for the test is based on three scenarios (Keong, C. & others):

- ✓ First scenario: If the computed statistic (F) is less than the critical value of the F-table, the null hypothesis suggesting no cointegration between variables (no long-term equilibrium relationship) is accepted.
- ✓ Second scenario: If the computed statistic (F) is greater than the critical value of the F-table, the alternative hypothesis suggesting cointegration between variables (existence of a long-term equilibrium relationship) is accepted.
- ✓ Third scenario: If the computed statistic (F) falls between the upper and lower critical values of the F-table, the results are inconclusive, meaning it is not possible to make a decision regarding whether there is cointegration between variables.

In the case of cointegration between variables, the next stage involves estimating the long-term equation using the following formula**:**

$$\mathrm{Yt} = \theta + \Sigma\, \sigma\mathrm{i}\, \mathrm{Yt}-\mathrm{i} + \Sigma\, \mathrm{ki}\, \mathrm{Xt}-\mathrm{i} + \varepsilon\mathrm{t} \ldots\ldots\ldots (8)$$

Where**:** X, Y: as previously defined/θ, σ, k: variable coefficients/ ε: random error term**.**

$$\Delta Yt = \mu + \Sigma\, \pi i\, \Delta\, Yt-i + \Sigma\, \omega i\, \Delta Xt-i + \gamma\, \varepsilon t-1 + \nu t \ldots\ldots\ldots (9)$$

The third stage involves obtaining the short-term relationship of the model by using the estimated residuals from one lag obtained from the long-term relationship in equation (8). Thus, the short-term relationship and error correction take the following form**:**

Where**:**

γ: error correction coefficient, measuring the speed at which deviations from short-term equilibrium are adjusted towards long-term equilibrium**.**

ν: random error term.

III-7 CUSUM Stability Test: Following the preceding steps, there arises a need to investigate whether these variables exhibit structural changes in their behavior over time, and the CUSUM (Cumulative Sum) stability test is one of the most commonly used tests in this field. The results of this test appear in the form of a curve of errors of a model estimated by the Ordinary Least Squares (OLS) method, along with a confidence interval to test the null hypothesis that the parameters of the OLS model are not stable. If the curve of errors stays within critical bounds throughout the study period, then the null hypothesis is rejected at a significance level of 5%. This implies that the parameters are stable over the study period, allowing for the estimation of fixed parameters for the model over the study period without the need for partitioning into sub-periods. However, if the null hypothesis is rejected, then it necessitates dividing the study period into sub-periods where the parameters are stable (Brown, & others, 1975)

VI- The results of the empirical study.

We give time series for the variables we used during the period (1990-2220) 32 views, and by applying logarithm to them to reduce the severity of their variation especially for variables with large numbers such as GDP and population... etc., and by following the methodology of applying the Autoregressive Distributed Lag (ARDL) model, we will try to estimate the equation of per capita carbon dioxide emissions by some economic variables in Algeria and the United States according to the literature of the study and comparing the results.

VI-1 Introducing the study variables:

- **Dependent Variable:**

✓ **CO2**: Carbon Dioxide Emissions (Average per capita in metric tons): The average per capita CO2 emissions in metric tons are estimated to measure the environmental impact of each individual in the country.

- **Independent Variables:**

✓ **DEP**: Final Government Expenditure on General Consumption (at current local currency prices): Represents government spending consumed by the public sector to purchase goods and services to meet public needs, such as education, health, infrastructure, and defense. This expenditure is usually measured at current local currency prices and reflects the size of general economic activity and government intervention in the economy.

✓ **GDP**: Gross Domestic Product (at current local currency prices): Defined as the value of all final goods and services produced within a country's borders during a specific period, whether by domestic or foreign companies. GDP is usually measured at current local currency prices and is considered a key indicator of the country's overall economic size.

✓ **P**: Population: Represents the number of individuals living in a particular country during a specified period. Population size is an important indicator of the country's population size and composition and is used in demographic analysis and guiding social and economic policies.

✓ **PCAP**: Per Capita Gross Domestic Product (in local currency): PCAP is an important indicator of the standard of living in the country, reflecting the average income available to each individual.

✓ **TR**: Trade Openness (% of Gross Domestic Product): Represents the size of a country's external trade exchange, usually measured as a percentage of GDP. Trade openness can reflect the extent of external economic influence on the local economy, with a higher percentage of trade openness usually indicating the degree of trade exchange and external influence on the economy.

IV-2 Stability of study variables: In order to test the stability of the time series of study variables, the Dickey-Fuller enhanced test and the Phillips-Perron test at level (0) were employed. Then, the first difference was applied to each series separately, followed by retesting, the results of which are shown in the following table:

Table N°2

(ADF) and (PP) test for the Study Variable Series Before and After Initial Difference

(Algeria)								H0 : Non-Stationary H1 : Stationary	variables
%	**Decision**	**Prob***	**level**	**%**	**Decision**	**Prob***	**level**		
%5	H(1)	0.0000	(1)	%5	H(0)	0.9074	(0)	ADF	**Log_CO2_DZA**
	H(1)	0.0000			H(0)	0.9175		PP	
	H(1)	0.0223			H(0)	0.3517		ADF	**Log_DEP_ DZA**
	H(1)	0.0248			H(0)	0.0365		PP	
					H(1)	0.0062		ADF	**Log _GDP_ DZA**
					H(1)	0.0000		PP	
	H(1)	0.0009			H(0)	0.7115		ADF	**Log _P_ DZA**
	H(0)	0.2097			H(0)	0.9152		PP	
	H(1)	0.0057			H(0)	0.8753		ADF	**Log _PCAP_ DZA**
	H(1)	0.0062			H(0)	0.8204		PP	
	H(1)	0.0001			H(0)	0.2600		ADF	**Log _TO_ DZA**
	H(1)	0.0002			H(0)	0.3634		PP	
(United States of America)								**H0 : Non-Stationary H1 : Stationary**	**variables**
%	**decision**	**Prob***	**level**	**%**	**decision**	**Prob***	**level**		
%5	H(1)	0.0001	(1)	%5	H(0)	0.9966	(0)	ADF	**Log _CO2_USA**
	H(1)	0.0000			H(0)	0.9069		PP	
	H(1)	0.2194			H(0)	0.6713		ADF	**Log _DEP_ USA**
	H(1)	0.1620			H(0)	0.6445		PP	
	H(1)	0.0028			H(0)	0.8005		ADF	**Log _GDP_ USA**
	H(1)	0.0030			H(0)	0.8005		PP	
					H(1)	0.0000		ADF	**Log _P_ USA**
					H(1)	0.0000		PP	
	H(1)	0.0000			H(0)	0.7689		ADF	**Log _PCAP_ USA**
	H(1)	0.0000			H(0)	0.7667		PP	
	H(1)	0.0000			H(0)	0.3373		ADF	**Log _TO_ USA**
	H(1)	0.0000			H(0)	0.3964		PP	

Source: Prepared by the researcher based on the data in Appendix (1) and (Eviews12)**.**

Through the tables above, we observe that the (Prob*) value from the (ADF) and (PP) tests for each series concerning Algeria and the United States of America at level (0) (before conducting first differences) was greater than (0.05), except for the series (Log GDP DZA) and (Log P USA), which remained stable at level (0) (Prob* value less than 0.05);

After conducting first differences on the remaining series, the (Prob*) value became less than (0.05), leading us to conclude that these series are stable at the first level (first difference), except for the series (Log P DZA), where the (ADF) and (PP) test results differed, and the (ADF) test was favored after the (ng-perron test), indicating stability at level (0) or level (1), allowing us to proceed with the stages of model estimation**.**

IV-3 Number of model delays: In this regard, the aforementioned indicators are calculated after estimating a Vector Autoregression (VAR) model, and based on the smallest value of them, the number of delays necessary to estimate the model is determined. Through Table (3), we observe an agreement of 4/5 indicators on 2 delays (P=2).

Table N°3

Number Of lags.

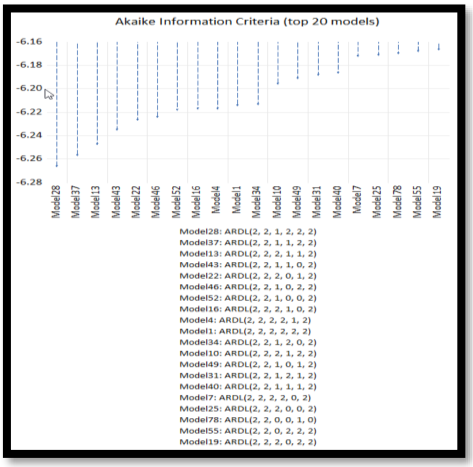
& Hannan Quinn	**Schwarz**	**Akaike**	**Final Prediction Error**	**Likelihood Ratio**	**lag**
(Algeria)					
-11.85923	-11.67216	-11.94970	2.60e-13	NA	**P=0**
-27.53301	-26.22350*	-28.16632	2.47e-20	444.9408	**P=1**
-27.86312*	-25.43118	-29.03927*	1.37e-20*	57.51958*	**P=2**
(United States of America)					
-20.76291	-20.57583	-20.85338	3.54e-17	NA	**P=0**
-37.41481	-36.10530	-38.04813	1.26e-24	468.4158	**P=1**
-39.11731*	-36.68536*	-40.29346*	1.78e-25*	82.22245*	**P=2**

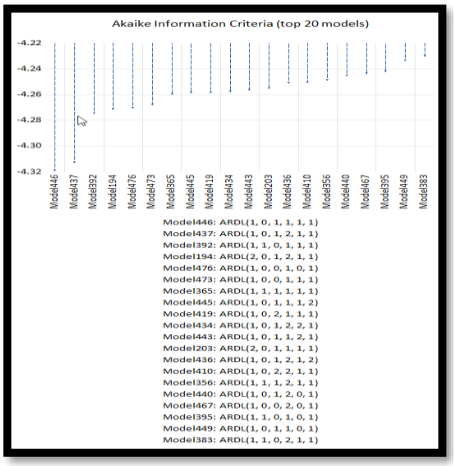
Source: Prepared by the researcher based on the data in Appendix (1) and (Eviews12)**.**

IV -4 Autoregressive Distributed Lag (ARDL) estimations: After ensuring the stability of the study variables and model stability, and determining the maximum number of lags it contains, the results of estimating the ARDL model came after identifying the best model from the possible combinations to choose, using the Akaike criterion, as follows: (ARDL 1.0.1.1.1.1) for the Algeria model and (ARDL 2.2.1.2.2.2) for the United States model.

Table N°4

Combinations Of The ARDL Model And Selection According To The Akaike Criterion

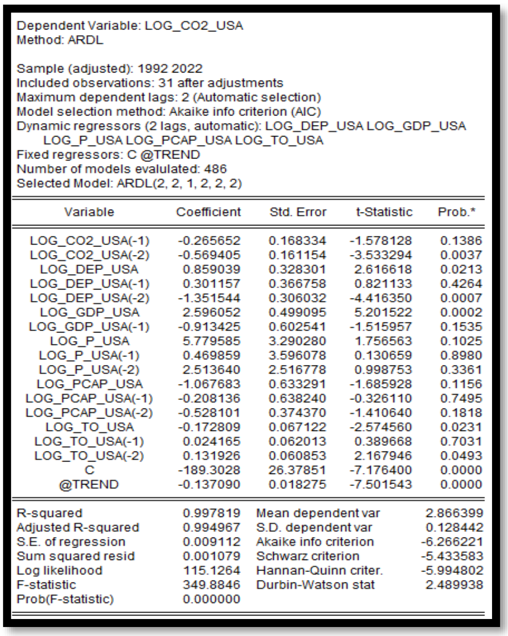




Source: Prepared by the researcher based on the data in Appendix (1) and (Eviews12)**.**

Table N°5

Estimation of the ARDL model for Algeria and the United States of America



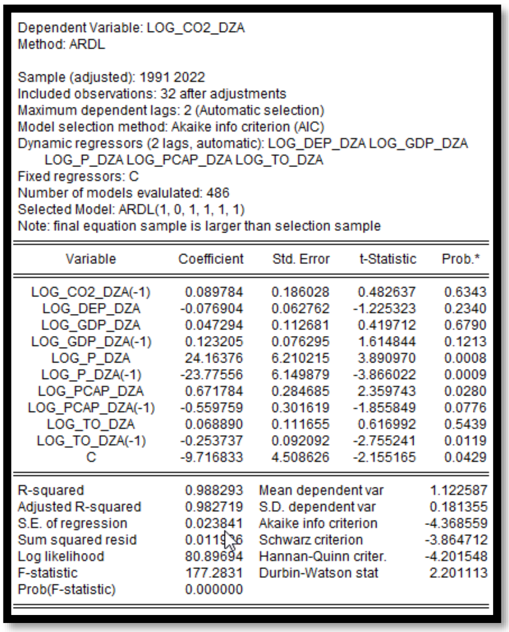
```
Dependent Variable: LOG_CO2_USA
Method: ARDL

Sample (adjusted): 1992 2022
Included observations: 31 after adjustments
Maximum dependent lags: 2 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic): LOG_DEP_USA LOG_GDP_USA
     LOG_P_USA LOG_PCAP_USA LOG_TO_USA
Fixed regressors: C @TREND
Number of models evalulated: 486
Selected Model: ARDL(2, 2, 1, 2, 2, 2)

       Variable         Coefficient   Std. Error   t-Statistic   Prob.*

  LOG_CO2_USA(-1)       -0.265652     0.168334     -1.578128     0.1386
  LOG_CO2_USA(-2)       -0.569405     0.161154     -3.533294     0.0037
    LOG_DEP_USA          0.859039     0.328301      2.616618     0.0213
  LOG_DEP_USA(-1)        0.301157     0.366758      0.821133     0.4264
  LOG_DEP_USA(-2)       -1.351544     0.306032     -4.416350     0.0007
    LOG_GDP_USA          2.596052     0.499095      5.201522     0.0002
  LOG_GDP_USA(-1)       -0.913425     0.602541     -1.515957     0.1535
     LOG_P_USA           5.779585     3.290280      1.756563     0.1025
   LOG_P_USA(-1)         0.469859     3.596078      0.130659     0.8980
   LOG_P_USA(-2)         2.513640     2.516778      0.998753     0.3361
   LOG_PCAP_USA         -1.067683     0.633291     -1.685928     0.1156
 LOG_PCAP_USA(-1)       -0.208136     0.638240     -0.326110     0.7495
 LOG_PCAP_USA(-2)       -0.528101     0.374370     -1.410640     0.1818
    LOG_TO_USA          -0.172809     0.067122     -2.574560     0.0231
  LOG_TO_USA(-1)         0.024165     0.062013      0.389668     0.7031
  LOG_TO_USA(-2)         0.131926     0.060853      2.167946     0.0493
         C             -189.3028     26.37851     -7.176400     0.0000
      @TREND            -0.137090     0.018275     -7.501543     0.0000

R-squared               0.997819   Mean dependent var        2.866399
Adjusted R-squared      0.994967   S.D. dependent var        0.128442
S.E. of regression      0.009112   Akaike info criterion    -6.266221
Sum squared resid       0.001079   Schwarz criterion        -5.433583
Log likelihood          115.1264   Hannan-Quinn criter.     -5.994802
F-statistic             349.8846   Durbin-Watson stat        2.489938
Prob(F-statistic)       0.000000
```



```
Dependent Variable: LOG_CO2_DZA
Method: ARDL

Sample (adjusted): 1991 2022
Included observations: 32 after adjustments
Maximum dependent lags: 2 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic): LOG_DEP_DZA LOG_GDP_DZA
     LOG_P_DZA LOG_PCAP_DZA LOG_TO_DZA
Fixed regressors: C
Number of models evalulated: 486
Selected Model: ARDL(1, 0, 1, 1, 1, 1)
Note: final equation sample is larger than selection sample

       Variable         Coefficient   Std. Error   t-Statistic   Prob.*

  LOG_CO2_DZA(-1)        0.089784     0.186028      0.482637     0.6343
    LOG_DEP_DZA         -0.076904     0.062762     -1.225323     0.2340
    LOG_GDP_DZA          0.047294     0.112681      0.419712     0.6790
  LOG_GDP_DZA(-1)        0.123205     0.076295      1.614844     0.1213
     LOG_P_DZA           24.16376     6.210215      3.890970     0.0008
   LOG_P_DZA(-1)        -23.77556     6.149879     -3.866022     0.0009
   LOG_PCAP_DZA          0.671784     0.284685      2.359743     0.0280
 LOG_PCAP_DZA(-1)       -0.559759     0.301619     -1.855849     0.0776
    LOG_TO_DZA           0.068890     0.111655      0.616992     0.5439
  LOG_TO_DZA(-1)        -0.253737     0.092092     -2.755241     0.0119
         C              -9.716833     4.508626     -2.155165     0.0429

R-squared               0.988293   Mean dependent var        1.122587
Adjusted R-squared      0.982719   S.D. dependent var        0.181355
S.E. of regression      0.023841   Akaike info criterion    -4.368559
Sum squared resid       0.011[illegible]6   Schwarz criterion        -3.864712
Log likelihood          80.89694   Hannan-Quinn criter.     -4.201548
F-statistic             177.2831   Durbin-Watson stat        2.201113
Prob(F-statistic)       0.000000
```

Source: Prepared by the researcher based on the data in Appendix (1) and (Eviews12)**.**

IV- 5 Diagnostic Tests: Before adopting and implementing the previously estimated model, it is necessary to ensure the quality of
its performance. This is done through conducting the following diagnostic tests:

Table N°6

Diagnostic test results

RAMSEY RESET		Normality test Jarque Bera	Serial Correlation LM Test	Heteroskedasticity Test		test
T- statistic	F-statistic			Breusch-Pagan-Godfrey	ARCH Test	
(Algeria)						
0.070661	0.004993	1.217063	0.505442	0.739724	1.157928	Value
0.9444	0.9444	0.544149	0.6111	0.6809	0.2908	Prop
(United States of America)						
0.108349	0.011739	0.469154	1.134875	0.607900	0.188073	Value
0.9155	0.9155	0.790905	0.3564	0.8336	0.6678	Prop

Source: Prepared by the researcher based on the outputs of Eviews 12**.**

❖ LM test, which is a test for the absence of autocorrelation in the residuals of the model, indicates the absence of a serial correlation problem in the residuals. The null hypothesis (H0) suggests no serial autocorrelation among the residuals of the model. It's observed that the corresponding probability for the calculated statistics for the first model (Algeria) (0.505442) with a probability of (0.6111) and the second model (W.M.O) (1.134875) with a probability of (0.3564) are both greater than (0.05), indicating the acceptance of the null hypothesis and acknowledging the absence of serial autocorrelation among the estimated residuals of the two models**.**

❖ As for the Heteroskedasticity Test, which utilizes two statistical tests: the Breusch-Pagan-Godfrey test and the ARCH Test, it fails to reject the null hypothesis (H0) indicating homoskedasticity in the model. It's noted that the probabilities corresponding to the calculated statistics for the tests are:

✓ Model (Algeria) (0.739724) with a probability of (0.6809) and (1.157928) with a probability of (0.2908), both greater than (0.05).

✓ Model (U.S.A) (0.607900) with a probability of (0.8336) and (0.188073) with a probability of (0.6678), both greater than**.(0.05)**

❖ Regarding the Normal Distribution Test of Residuals, it indicates acceptance of the null hypothesis (H0), suggesting that the residuals of the model are normally distributed. The calculated statistics (Jarque Bera) equal (1.217063) with a probability of (0.544149) in the Algeria model and (0.469154) with a probability of (0.790905) in the model specific to the United States, both probabilities being greater than **(0.05).**

❖ The RAMSEY RESET test is used to measure the adequacy of the functional form employed in the estimated model, which assumes the null hypothesis (H0) regarding the correctness of the functional form. The results of this test in both the first and second models indicated that the statistical probability, as shown by the F-test and t-test is greater than 0.05, implying acceptance of the null hypothesis. This suggests the validity of the functional form used in both models**.**

What matters most to us in these tests is that the estimated model doesn't contain any autoregressive relationship between residuals, as well as the stability of the variance of the random error. Hence, we can now conduct boundary tests to detect the equilibrium relationship between variables.

IV- 6 Bounds Testing Approach: The results of this test are illustrated in the following table:

Table N°7

F-Bounds Test results

(Algeria)						
Number of independent variables K=5					F-Bounds Test	
%1	%2,5	%5	%10	level of significance α		
3.41	2.96	2.62	2.26	Lower bound value	f-critical	F
4.68	4.18	3.79	3.35	Upper bound value		
5.283063					f -value	
There is a cointegration relationship	There is a cointegration relationship	There is a cointegration relationship	There is a cointegration relationship	Decision		
(United States of America)						

Number of independent variables K=5					**F-Bounds Test**	
%1	%2,5	%5	%10	level of significance **α**		
3.93	3.49	3.12	2.75	Lower bound value	f-critical	**F**
5.23	4.67	4.25	3.79	Upper bound value		
13.35872					f -value	
There is a cointegration relationship	There is a cointegration relationship	There is a cointegration relationship	There is a cointegration relationship	Decision		

Source: Prepared by the researcher based on the outputs of Eviews 12**.**

Based on the results in the table above, it can be observed for both countries under study (Algeria and the United States of America) that the calculated Fisher statistical value exceeds the critical values for the upper limit, with confidence levels (10%, 5%, 2.5%, 1%). Therefore, we reject the null hypothesis and accept the alternative hypothesis, which suggests the existence of a long-term equilibrium relationship between the independent and dependent variables.

It is worth noting that many researchers neglect testing the t-Bounds Test and suffice with only testing the F-Bounds Test to prove the existence of cointegration. The F-test examines the long-run levels of all variables, while the t-test takes into account the coefficients of the lagged levels of the dependent variable. In this case, the conclusions may be incorrect and termed as an illogical and deteriorated case of common integration, where the F-statistic might be significant, but when the t-statistic is neglected, the coefficients on the lagged levels of the dependent variable may not differ significantly from zero. Consequently, it leads to the judgment of the absence of common integration among the series in the model. Additionally, if the null hypothesis for the F-test is rejected, it indicates the presence of a common integration relationship, but it does not specify its type, and the procedures for error correction based on the correction coefficient are not completed until the t-test is conducted to ensure that the common integration is logical and regular (ideal).

Table N°8

t–Bounds results

(Algeria)						
Number of independent variables K=5					t-Bounds Test	
%1	%2,5	%5	%10	level of significance **α**		
3.43-	3.13-	2.86-	2.57-	Lower bound value	f-critical	**t**
4.79-	4.46-	4.19-	3.86-	Upper bound value		
4.892904-					f -value	
Logical cointegration	Logical cointegration	Logical cointegration	Logical cointegration	Decision		
(United States of America)						
Number of independent variables K=5					t-Bounds Test	
%1	%2,5	%5	%10	**level of significance α**		
5.13-	4.79-	3.41-	3.13-	Lower bound value	f-critical	**t**
3.96-	3.65-	4.52-	4.21-	Upper bound value		
6.947618-					f -value	
Logical cointegration	Logical cointegration	Logical cointegration	Logical cointegration	Decision		

Source: Prepared by the researcher based on the outputs of Eviews 12**.**

IV- 7 Estimate the short-run equation and error correction (ECM): In short-term analysis, researchers are not so concerned about the short-term effects of independent variables on the dependent variable as they are about long-term equilibriums. In this regard, we will suffice with the results of a short-term equation by analyzing the degree and speed of error correction through the error correction parameter (ECM*)*.

Table N°9

Results of short-run equation and error correction parameter (ECM)**.**

United States of America		
Independent variable	**coefficients**	**signification**
C	**-189.3028**	**0.0000**
@TREND	**-0.137090**	**0.0000**
D(LOG_CO2_USA(-1))	**0.569405**	**0.0001**
D(LOG_DEP_USA)	**0.859039**	**0.0001**
D(LOG_DEP_USA(-1))	**1.351545**	**0.0001**
D(LOG_GDP_USA)	**2.596052**	**0.0000**
D(LOG_P_USA)	**5.779587**	**0.0311**
D(LOG_P_USA(-1))	**-2.513641**	**0.2472**
D(LOG_PCAP_USA)	**-1.067683**	**0.0060**
D(LOG_PCAP_USA(-1))	**0.528101**	**0.0082**
D(LOG_TO_USA)	**-0.172809**	**0.0004**
D(LOG_TO_USA(-1))	**-0.131926**	**0.0016**
CointEq(-1)*	**-1.835057**	**0.0000**

Algeria		
Independent variable	**coefficients**	**signification**
C	**-9.716834**	**0.0000**
D(LOG_GDP_DZA)	**0.047294**	**0.4032**
D(LOG_P_DZA)	**24.16376**	**0.0000**
D(LOG_PCAP_DZA)	**0.671784**	**0.0027**
D(LOG_TO_DZA)	**0.068890**	**0.3397**
CointEq(-1)*	**-0.910216**	**0.0000**

Source: Prepared by the researcher based on the outputs of Eviews 12**.**

From the table above, we observe that the error correction coefficient equals (-0.910216) (-1.835057) in Algeria and the United States respectively, where both the sufficient condition (negative sign) and the necessary condition (statistical significance (0.0000)) are met. Thus, the error correction mechanism (ECM) coefficient reveals the speed of adjustment of the dependent variable (per capita carbon dioxide emissions) towards its equilibrium value in the long run. In each time period (year), the proportion of imbalance correction is estimated at (91.02%) and (183.50%) respectively, which signifies a very high adjustment coefficient, particularly for the United States. In other words, when the per capita carbon dioxide emissions deviate due to a shock in the rate itself or in one of the variables affecting it during the short term (t-1) from its equilibrium value, it is corrected in Algeria by an equivalent of (91.02%) per year, which translates to complete correction within a year and three months (1/0.910216=1.1), and in the United States by (183.50%) per year, implying complete correction within half a year (1/1.835057=0.55) until reaching equilibrium in the long run.

The rapid correction of errors in two equations is attributed to the nature of the dependent variable (CO2), which is considered a gaseous substance. Carbon dioxide gas is known for its chemical and physical properties characterized by rapid dispersion and uniform distribution in the environment. Since gases disperse quickly and are influenced by multiple factors beyond the economic factors included in the standard model, any changes in these factors can lead to rapid and significant effects on the average value. Due to the rapid dispersion and effects of gases, corrections are made quickly to restore the system to its equilibrium value in the long run**.**

IV-8 Estimate the long-run equation.

Table N°10

Long-run equation estimation.

United States of America	
Independent variable	**coefficients**
LOG_DEP_USA	**-0.104274**
LOG_GDP_USA	**0.916934**
LOG_P_USA	**4.775374**
LOG_PCAP_USA	**-0.983033**
LOG_TO_USA	**-0.009111**
EC = LOG_CO2_USA - (-0.1043*LOG_DEP_USA + 0.9169*LOG_GDP_USA + 4.7754*LOG_P_USA - 0.9830*LOG_PCAP_USA -0.0091*LOG_TO_USA)	

Algeria	
Independent variable	**coefficients**
LOG_DEP_DZA	**-0.084490**
LOG_GDP_DZA	**0.187316**
LOG_P_DZA	**0.426486**
LOG_PCAP_DZA	**0.123074**
LOG_TO_DZA	**-0.203080**
EC = LOG_CO2_DZA - (-0.0845*LOG_DEP_DZA + 0.1873*LOG_GDP_DZA +0.4265*LOG_P_DZA + 0.1231*LOG_PCAP_DZA -0.2031*LOG_TO_DZA)	

Source: Prepared by the researcher based on the outputs of Eviews 12**.**

From the table above, we notice the long-term relationship estimation between the dependent variable (CO2: average per capita carbon dioxide emissions) and the independent variables (DEP:

final government consumption expenditure / GDP: Gross Domestic Product / P: population / PCAP: per capita GDP / TO: trade openness) as follows:

✓ The results of the long-term relationship for Algeria and the United States within the ARDL methodology framework show similar signs of the coefficients of the independent variables on the dependent variable, with varying degrees and a single difference in sign regarding the independent variable (PCAP: per capita GDP).

✓ DEP (final government consumption expenditure) has an inverse effect (negative sign) on the average per capita carbon dioxide emissions. However, this effect is very slight compared to the impact of other variables. Perhaps this is due to some government spending being directed towards environmental policies, including pollution reduction and carbon dioxide emission reduction. The effect of this variable in the United States (-0.104274) is more significant than in Algeria (-0.084490).

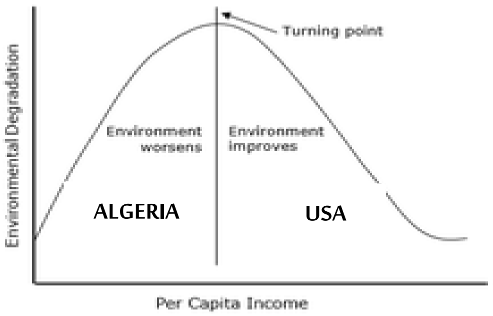
✓ The inverse relationship of GDP (Gross Domestic Product) and P (population) with CO2 emissions may reflect the reality that economic growth and population density often accompany increased production, consumption, and energy use due to intensive economic activity, which can lead to increased CO2 emissions.

✓ The inverse relationship between TO (trade openness) and CO2 emissions may indicate that countries more open to global trade tend to import fully manufactured goods from other countries, which are more energy-intensive, thereby avoiding local production and emissions. This makes them able to export energy, thus reducing local carbon dioxide emissions.

✓ The reason for the difference in sign regarding the independent variable (PCAP: per capita GDP), employing a "Kuznets Curve" approach, can be explained by noting that the Algerian economy and the level of per capita income have not yet reached a point where their impact is negatively correlated with average per capita carbon dioxide emissions, unlike the United States. Higher income levels lead to increased environmental awareness and adoption of environmental measures and practices that reduce carbon emissions, such as the use of public transportation and investment in improving energy efficiency in homes, buildings, and facilities, thereby reducing fossil fuel consumption and consequently carbon emissions.

Figure N° 4

The position of Algeria and the United States of America on the “Kuznets Curve”



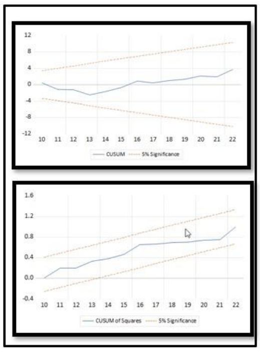
Source: Prepared by the researcher based on the “Kuznets Curve” approach.

IV- 8. Structural Stability Test Results for Estimated ARDL Model: Based on Figure 3, it is evident that the estimated coefficients of the ARDL model remain stable throughout the study period. This indicates the presence of stability among the analyzed variables and consistency in the model's results regarding short and long-term error correction. Additionally, graphical representation of the structural stability tests for this model falls within critical bounds at a significance level of 5%, thus supporting the notion of stability.

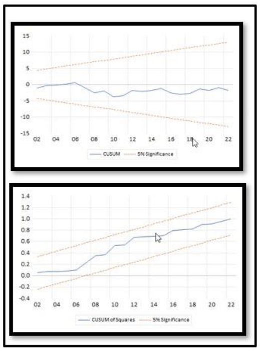
Figure N° 5

Structural stability test of the estimated ARDL model.

Structural stability of the estimated ARDL model in (USA)



Structural stability of the estimated ARDL model in (Algeria)



Source: Prepared by the researcher based on the outputs of Eviews 12**.**

Conclusion :

Several landmark studies have shown that carbon dioxide emissions resulting from fossil energy consumption, such as gas, oil, and coal, are projected to surpass their historic levels in the coming years, following a tangible decline due to the COVID-19 pandemic. Therefore, transitioning to a future marked by reduced carbon emissions is a complex and challenging process, especially as alternative energy sources require substantial sustainable investments and significant time to meet the growing global energy demand. To ensure energy security and meet the needs of an increasing global population, it is inevitable that hydrocarbon energy sources will continue to play a key role in meeting the majority of global energy needs in the foreseeable future.

Our study has demonstrated the importance of the Autoregressive Distributed Lag (ARDL) approach in studying macroeconomic variables. This model combines elements of the Distributed Lag Model and the Autoregressive Model. The ARDL methodology provides efficient and unbiased estimates, allowing for the identification of critical values for the tests used. Additionally, the ARDL model permits explanatory variables to have different time lags, a feature not allowed by other standard models. Our estimation using this model to determine the economic determinants of per capita carbon dioxide emissions in Algeria and the United States revealed that in the short run, the error correction rates are estimated to be 91.02% and 183.50%, respectively, indicating very high adjustment coefficients, especially for the United States. In the long run, the equations for both Algeria and the United States within the ARDL framework show the same signs for the coefficients of the independent variables on the dependent variable, albeit with varying degrees of significance. The only difference lies in the sign regarding the independent variable (PCAP: per capita income). This discrepancy is attributed to the fact that the Algerian economy and the level of per capita income have not yet reached a point where their impact on per capita carbon dioxide emissions is negative (inverse effect), unlike the United States. Higher income levels lead to increased environmental awareness and adoption of environmentally friendly measures and behaviors, such as the use of public transportation and investment in improving energy efficiency in homes, buildings, and facilities, thereby reducing fossil fuel consumption and carbon emissions

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