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THE RELATIONSHIP BETWEEN ENVIRONMENTAL QUALITY AND ECONOMIC GROWTH: AN EMPIRICAL INVESTIGATION APPLIED TO THE CASE OF ALGERIA (1970-2019)[3]

The aim of this paper is to study the existence of an environmental curve for the case of Algeria using the two-degree polynomial function presented in the linear and semi-log-linear and log-linear form in order to detect the effect of international trade and people on environmental quality. To reach our goal, we have structured our paper around two elements: Firstly, we will present a brief review of empirical and theoretical literature on the relationship between economic growth and the quality of the environment. Secondly, we will deal with the empirical study evaluating the impact of the issue of CO_2 *on economic activity. We have found that the environmental Kuznets curve (EKC) exists in Algeria and the GDP per capita and the population have a positive impact on the emission of the* CO_2*. Furthermore, trade openness has a negative impact. In addition, there is a stable long-term relationship between emissions of* CO_2 *and the others various explanatory variables (GDP per capita, international trade and population).*
Keywords: environmental quality; environmental Kuznets curve; economic growth; population; international trade; trade openness; environmental pollution; autoregressive distributed lag
JEL: C12; C22; Q56

Introduction

Different studies have shown that since 1970, carbon gas emissions in the world have multiplied, it is expected that this continuous effect of emissions will induce an increase in heat in the world of 0.7% in 2050 with all its consequences in the different areas (quality of life, government spending, natural disasters, etc.). At the same time, the continuity of the level of production in the various activities and at a sustained way, following trade liberalization, the increase in the level of trade, economic opening and all that accompanies such development of effects of secondary gases like carbon monoxide and other warming

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gases in the open air, and as a result of the increase in the degree of heat, the sea level; the whole of these induced effects will negatively influence agricultural production and cause a shortage in the supply of drinking water, an expansion of diseases and others negatives externalities. Faced with the pressure of social movements, international political decision-makers (ex Cop21) have been pushed to become aware of this state of disrepair, towards which we are moving to take measures to reduce these effects of pollution in the air and among them the most important carbon monoxide gas. To achieve the environmental objectives imposed on the Algerian economy, while pursuing its development policy which displays a change (a trade policy of free trade which has favoured a modification of the locations of industries) to adapt to the liberalization movements that the world economy have seen so as to bring about a strengthening of restrictive environmental legislation in order to avoid the examples linked to the sad natural disasters that have occurred to a set of countries in different areas.

The disasters of Seveso, Bhopal, the grounding of Erika and the Exxon Valdez, which caused a major oil spill and Chernobyl radiation, are all proven examples with releases into the environment that do not leave any ambiguity as to their source and potential danger. There is no country in the world, which is not safe from disasters, but it is usually the poorest countries that pay the highest price in human lives. The international dimension of disasters is their consequences, the damage they cause, but also sometimes their origins.

The relationship between economic growth and the quality of the environment takes an important place in the economic literature to become a great interest for economists and which has its origin in the hypothesis of the Environmental Kuznets curve (EKC). Several empirical works have attempted to make a link between environmental quality and economic growth. We can quote the works of Grossman and Kruger (1991, 1994), Shafik and Bandyopadhyay (1992), Cropper and Griffith (1994), Selden and Song (1994), Antle and Heidebrink (1995), Holtz-Eakin and Selden (1995), Majid Ezzati, Singer Burton H, et Daniel M Kammel (2001), David I. Stern (2004), Rob Hart (2020), Pincherra R and Zuniga F (2020).

Through this paper, we address the following issue: Is there a relationship between environmental quality and economic growth in Algeria? To analyze this problem, we set ourselves two objectives for this study:

1) Check if there is an EKC for the Algerian case using the two-degree polynomial function presented in linear, semi-log-linear and log-linear form.

2) Analyze the impact of international trade and the increase in the population in the level of CO_2 emissions.

This work derives its interest from the importance assumed by the dimension of environmental protection in such a way as not to jeopardize the lives of future generations within the framework of the application of the EKC. We realize that it exists an ever-increasing development in economic relations within the context of new global changes that involve different actors (governmental and non-governmental institutions) to be concerned with the existence of a healthy environment which can benefit all countries.

In order to achieve our objective, we have structured our work around fourth points: In the first point, we will present a brief review of the empirical and theoretical literature on the relationship between economic growth and the quality of the environment. In the second point, we will use an empirical study to assess the impact of the emission of CO_2 on economic activity (Model specification of the EKC). In the third point, we present the extended polynomial model of the EKC. In the fourth point, we will present the interpretation of the results. A concluding remark is presented at the end of this work.

1. Review of Theoretical and Empirical Literature

1.1. Theoretical literature review

In economic theory, the relationship between economic growth and environmental quality is derived from the Environmental Kuznets Curve (EKC) hypothesis, which states that as a country develops, it is experiencing with a low growth, degradation and pollution increase. A greater environmental deterioration begins with low levels of income. But after reaching a high level of economic development, a better level of income, pollution will tend to decrease and cause an improvement in environmental quality. As the income increases, there is more requirement for investors to reduce environmental damage. A higher GDP makes it easier to have enough resources to finance environmental policies. So for the government, when the incomes are high, it is easier to reserve part of its consumption to protect the environment. The economic growth would be linked probably with environmental improvement. This shows that the influence and environmental impact is represented by an inverted U per capita income.

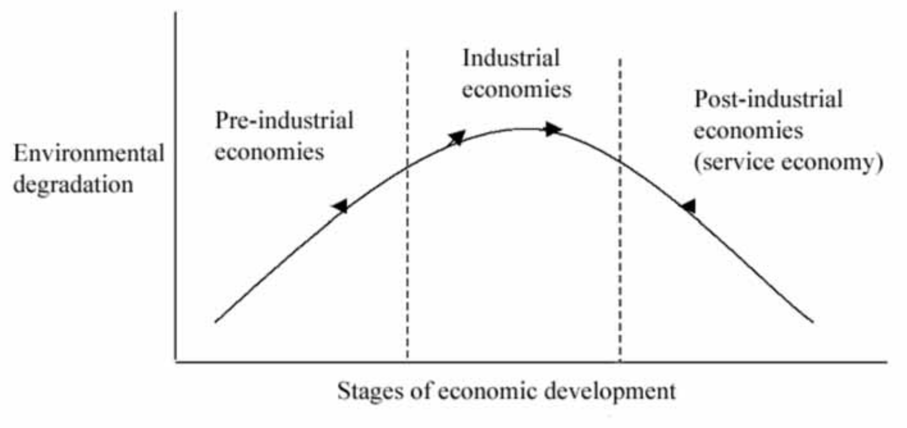
In fact, environmental degradation is inevitable at the start of a country's economic growth. In other words, the access to a sufficient level of economic development, the importance of problems related to sustainable development and the environment and efforts to prevent environmental degradation. The economic growth is achieved with less environmental damage.

The representation of the general shape of the Kuznets environmental curve is presented in Chart 1.

The developments on this subject tell us that the debate on the environment and economic growth has centred on these five main questions: The first one, the hypothetical inverted U-shaped relationship between income and environmental degradation, known as the *Environmental Kuznets Second'*. The second question explains the role played by others factors, such as population growth, income distribution, international trade, time and space as dependent variables. The third one showed how the economy of a country could be changed. The last one explained the implications of ecological thresholds and irreversible damage for the inverse relationship between environmental degradation and economic growth, namely, whether a static statistical interpretation can be interpreted in terms of carrying capacity, ecosystem resilience and sustainability. Finally, the role of environmental policy interferes in the treatment of the shape of the relationship linking income and environment to reduce the economic cost of economic growth and ensure more sustainable results.

Chart 1

The Kuznets Environmental Curve



Source: Theodore Panayotou, (2003)

1.2. The presentation of the empirical review on this relationship

The theoretical background can be divided into two categories: One using panel methods, the others with time series methods.

- **Studies carried out on panel data**

Shafik and Bandyopadhyay (1992), tried to validate the EKC on a sample of 149 countries during the period 1960-1990 by taking three environmental indicators: the emission of sulfur dioxide (SO_2,) deforestation and carbon emission. They found that the inverted U shape was only validated for SO_2. The turning point values alternate between 2000 and 4000 (US $ 1985). Grossman and Krueger (1991, 1995) studied the existence of EKC on a sample of developed and developing countries using a range of environmental indicators to integrate them into the random-effects model. They proved the inverted U shape for water pollution and SO_2, and the turning point varies between 4000 and 5000 (US $ 1985). Selden and Song (1994) took four pollutants (SO_2, SPM, NOx and CO_2). An inverted U curve was verified for the all four pollutants. The turning points exceed $ 8,000 1985 in the case of SO_2 and SPM. Cropper and Griffith (1994) considered a sample of 64 countries over the period 1961–1991 using deforestation as an environmental indicator. They found an inverted U-curve for Africa and Latin America, with the turning points alternating between 4760 and 5420 (in US $ 1985). Harbaug W, Levinson A and Wilson D [2000] used the air pollution data used by Grossman and Krueger (op cited), however they came to conflicting results displayed by Grossman and Krueger. They questioned the existence of an inverted U-shaped relationship between pollution and per capita income. The work presented by Meunié A and Pouyanne G (2007) aims to test the EKC "U" hypothesis for 37 cities around the world. they presented three results. They estimated the quadratic relations were giving many bell-shaped curves for the sample. Then, they showed that the curves are explained by two sets of factors: individual behaviours, and collective choices. Finally, they checked the validity of the hypothesis of the

CEK "U" by seeking to explain more generally the level of polluting emissions. Nkengfack H., Kaffo F. (2014), using an ARDL model, examined the effects of economic growth on carbon dioxide (CO_2) emissions in a few countries of the Congo Basin over the period 1978-2012. By this model, they showed that economic growth has a positive impact on CO_2 emissions in these countries. Then, they found that energy consumption, population density, industrial activities increase CO_2 emissions, although the impact of energy consumption and industrial activities are not significant in DRC. Trade openness has a negative and significant impact on CO_2 emissions in Cameroon, while its impact is insignificant in Congo, Gabon and DRC. This result contradicts the hypothesis of pollution "havens".

- **Studies carried out on time series**

Roca and Alcantara (2001) studied the validity of the EKC hypothesis for the case of Spain over the period 1972-1997; they demonstrated that the U-shaped curve between CO_2 emissions and GDP per capita is not verified. Soytas et al. (2007) studied the validity of the EKC hypothesis for the case of the United States over the period 1960-2004 and the existence of causality between income, energy consumption and CO_2 emissions. They proved the validity of the EKC hypothesis and established the existence of a unidirectional Granger causal relationship that goes in the direction of energy consumption towards CO_2 emissions. Pao and Tsai (2011) have tested the validity of KEC in Brazil by the ARDL approach using annual data of GDP and emissions of dioxide CO_2. Their results show the existence of KEC in Brazil. Saboori and Sulaiman (2013) tried to validate the existence of EKC in the case of Malaysia by introducing energy consumption into their equations. They found that EKC does not exist and that there is a two-way causality between the emission of carbon dioxide CO_2 and GDP. Yavuz (2014) studied the validity of the EKC hypothesis for the case of Turkey during the period 1960-2007 using the ARDL model. He confirmed the hypothesis of EKC.

Moreover, Farhani et al. (2014) studied the dynamic relationship between carbon dioxide (CO_2) emissions, production (GDP), energy consumption and trade using the ARDL approach for the case of Tunisia during the period 1971-2008. The empirical results reveal the existence of two long-term causal relationships between the variables. In the short term, there are three unidirectional Granger causal relationships, which gone from GDP, from squared GDP and energy consumption to CO_2 emissions dioxide. Toumache (2009) examined the existing relationship between CO_2 and economic growth in Algeria over the period 1993 -2006, and he found contradictory results with the logic of Kuznets models. Noubissi E-D and Njangang H-N (2017) examined the effects of economic growth on carbon dioxide (CO_2) emissions and temperature trends in Cameroon over the period 1972–2010. Using the ARDL model, they found the existence of a long-term relationship in the form of "inverted N" between economic growth and indicators of environmental degradation (CO_2 emissions and temperature change). They found that in Cameroon, energy consumption and industrial activities increase CO_2 emissions but not temperature changes. On another side, trade opening leads to a drop in the level of CO_2 but not in temperature.

2. Model Specification of the EKC

In this point, we will check if there is EKC for the Algerian case by using the polynomial function of degree two presented in linear, semi-log-linear and log-linear form. Then we will expand this function by adding two explanatory variables other than the GDP per capita, namely international trade and the population, as control variables to detect their effect on environmental quality.

2.1. The specification polynomial model of the EKC

Referring to the studies presented by Toubache Rachid (2009) and Maamar Sabri (2009), we will examine the direct relationship between the evolution of the CO_2 per capita and GDP per capita by a polynomial function of degree two presented in linear, semi-log-linear and log-linear form. The three models are presented as follows:

$$CO_{2_t} = a_0 + a_1 GDP_t + a_2 GDP_t^2 + \varepsilon_t \quad (1)$$

$$CO_{2_t} = \alpha_0 + \alpha_1 \log GDP_t + \alpha_2 (\log GDP_t)^2 + v_t \quad (2)$$

$$\log CO_{2_t} = \beta_0 + \beta_1 \log GDP_t + \beta_2 (\log GDP_t)^2 + w_t \quad (3)$$

Where CO_2 is the per capita emissions of the CO_2 which is an indicator of pollution, GDP_t is the per capita income. a_i , α_i et β_i represent model parameters. ε_t , v_t and w_t represent the terms of the error. In order for the relationship between the CO_2 per capita emissions and per capita income to demonstrate the existence of a "bell" shape, it is necessary that:

$$a_1 > 0 \text{ and } a_2 < 0$$
$$\alpha_1 > 0 \text{ and } \alpha_2 < 0$$
$$\beta_1 > 0 \text{ and } \beta_2 < 0$$

2.2. The unit root test

Before estimating the parameters of the three equations (1, 2, 3), we will study the stationarity of these variables of equations 1, 2 and 3 by the ADF (Dukey Fuller Augmented) test. The application of the ADF test (Dickey and Fuller 1979; 1981) requires beforehand the choice of the number of delay "p" to introduce so as to whiten the residues. The delay “p” value is determined either using the partial autocorrelations function, or using the Box-Pierce statistic, or again using the Akaike criteria (AIC) or finally by Schwartz (SC).

In our study, we applied the ADF test and we determined the number of delays using the partial autocorrelations function to study the significance of the partial correlation coefficients. The application of this method, based on the "correlogram" study of the different variables of the equation (1), allowed us to obtain the delay "one" for all the variables.

Table 1

Augmented Dickey-Fuller test for the variables of the three equations

Variables of Equation 1			
In level			
Variables	(1)	(2)	(3)
CO_{2_t}	-2,19	-1,85	0,90
GDP_t	-1,47	-1,07	1,96
GDP_t^2	-1,16	-0,62	2,22
In difference			
ΔCO_{2_t}	-3,59*	-3,58*	-3,16*
ΔGDP_t	-3,22*	-3,30*	-3,29*
ΔGDP_t^2	-2,89*	-2,92*	-2,86*
Variables of equation 2			
In level			
CO_{2_t}	-2,19	-1,85	0,90
$\log GDP_t$	-1,87	-1, 50	1,73
$(\log GDP_t)^2$	-1,82	-1,45	1,75
In difference			
ΔCO_{2_t}	-3,59*	-3,58*	-3,16*
$\Delta \log GDP_t$	-3,77*	-3,97*	-4,01*
$\Delta(\log GDP_t)^2$	-3,69*	-3,87*	-3,90*
Variables of equation 3			
In level			
$\log CO_{2_t}$	-2,98	-3,18	-0,19
$\log GDP_t$	-1,87	-1, 50	1,73
$(\log GDP_t)^2$	-1,82	-1,45	1,75
In difference			
$\Delta \log CO_{2_t}$	-3,19**	-2,88*	-2,55*
$\Delta \log GDP_t$	-3,77*	-3,97*	-4,01*
$\Delta(\log GDP_t)^2$	-3,69*	-3,87*	-3,90*

(1), (2) and (3) indicate the models "with constant and trend", "with constant" and "without constant and without trend"

* indicates Significance levels at 5%

** indicates the Significance levels at 10%

After determining the delay for each variable, we adopted the sequential strategy of the ADF test to investigate the stationarity of the variables in our study.

The table below shows the results of the Dickey-Fuller Augmented Tests (ADF) for the variables of these three equations (1, 2, 3). We are testing:

The null hypothesis H0: Non-Stationarity;

Against The alternative; hypothesis H1: Stationarity.

The results of the unit root test presented in the table above, show that all the series of the three equations are non-stationary in level, but they are stationary in difference. They are therefore integrated of order 1.

2.3. The Johansen's cointegration test.

The Johansen Trace test allows us to detect the number of the co-integrating vectors. The hypotheses of this test are:

there are at most “r“ cointegration vectors;

there are at least “r“ cointegration vectors.

We accept when the Trace statistic is below critical values at a significance level of $\alpha\%$.

However, we reject otherwise. This test is applied sequentially from r = 0 to r = k-1.

Table 2

The Johansen cointegration test

The cointegration between the variables of the model 1			
Eigen value	Trace statistic	Critical value	Hypothesized on the number of Ces
0.811811	100.8360	29.79707	Any
0.338128	20.66123	15.49471	At least one
0.017602	0.852411	3.841466	At least two
The cointegration between the variables of model 2			
0.898036	130.9810	29.79707	Any
0.344627	21.39054	15.49471	At least one
0.022822	1.108128	3.841466	At least two
The cointegration between the variables of the model 3			
0.887678	125.0475	29.79707	Any
0.333479	20.10114	15.49471	At least one
0.013005	0.628340	3.841466	At least two

Table 2 shows the application of the Johansen Trace test between the variables to each model (linear, semi-log and logarithmic). This test allows us to conclude that there are two co-integrating relationships. Therefore, emissions of the CO_2 per capita and GDP per capita are co-integrated.

2.4. The estimation of the long-term equation

Having confirmed the presence of a co-integrating relationship between the variables, it is interesting to analyze the detailed results of the long-term relationship. We estimate the long-term relationship by the "OLS" method for the three models:

$$CO_{2_t} = -5,97 + 0,003 GDP_t - 3,07 \times 10^{-7} GDP_t^{2} + \varepsilon_t$$

(-2,99) (−2,22) (3,17) (4)

$\bar{R}^2 = 0,70$ F-Statistic = 58,62 P(F-Statistic) = 0,0000 DW=0,28

$$CO_{2_t} = -148,03 + 16,4 \log GDP_t - 0,44 \ (\log GDP_t)^2 + v_t$$

(-1,35) (1,22) (-1,08) (5)

$\bar{R}^2 = 0,70$ F-Statistic = 58,5 P(F-Statistic) = 0,0000 DW=0,32

$$\log CO_{2_t} = -247,9 + 29,18 \log GDP_t - 0,85 \ (\log GDP_t)^2 + w_t$$

(-3,71) (3,58) (-3,44) (6)

$\bar{R}^2 = 0,71$ F-Statistic = 61,44 P(F-Statistic) = 0,0000 DW=0,55

We note through the results obtained from equations (4, 5 and 6) that all the coefficients of these equations are significant at the 5% level, except the coefficients of equation 5 (semi logarithmic), which are not significant, however, all have the right or correct sign. Thus, the coefficients a_2, α_2 et β_2 are negative, but on the other side the coefficients a_1, α_1 and β_1 are positive, which makes it possible to validate the existence of a EKC, including:

The diversion point $\frac{-a_1}{2a_2}$ would be at an annual income level of 4885.99 \$ per capita for the linear model.

The diversion point exp $\frac{-\alpha_1}{2\alpha_2}$ would be at an annual income level of \$ 124,070,888 per capita for the semi-linear model.

The diversion point exp $\frac{-\beta_1}{2\beta_2}$ would be at an annual income level of \$ 28,479,807.4 per capita for the log-linear model.

The static relationship between the emissions of CO_2 per capita and income per capita is statistically acceptable, because P (F-Statistic) is less than 5%. The explanatory power is around 70% for the three models and the residuals are normally distributed.

2.5. The choice between the three specific economic models: linear, semi-linear and log-linear

We discard the semi-logarithmic model of our study, because its coefficients are not significant (they are not verified by the t-statistic), we have to make a choice between the linear model and the log-linear model by the use of three information criteria: Akaike info criterion (AIC), Schwarz criterion (SC) and the Hannan-Quinn criterion (HQ).

Table 3

The choice between the three specific models

Models	The choice criteria		
	AIC	SC	HQ
The linear model	1,11	1,22	1,15
the log-linear model	0,12	0,24	0,17

The three criteria show that the log-linear model is chosen, retained. For this purpose, we will extend

this model by adding two explanatory variables others than GDP per capita as control variables to study its impact on the level of the emissions of the $CO_{2.}$

3. The Extended Polynomial Model of the EKC

3.1 The specificity of the model and description of the variables

We will expand the polynomial model by adding two explanatory variables other than GDP per capita, namely international trade and population density in order to examine the effect of population density and international trade on the evolution of the emissions of the CO_2. The international trade is measured by the Trade Openness Index. This index is like the ratio of the sum of export (X) and import (M) to GDP [(X + M) / GDP].

Our model is inspired by that of Sebri Maamar (2009), which can be presented as follows:

$$\log CO_{2t} = \alpha_1 \log GDP_t + \alpha_2 \log GDP_t^2 + \alpha_3 \log dPOP_t + \alpha_4 \log OPEN_t + u_t \qquad (7)$$

Where CO_2 is the per capita carbon dioxide emissions. It is used as a proxy for air pollution and as an indicator of environmental quality. GDP is the Gross Domestic Product per capita, it is used as an indicator of economic growth, GDP_t^2 is the gross domestic product per capita squared, dPOP is the population density, $OPEN_t$ is the trade openness ratio used as a proxy for international trade, α_1, α_2, α_3 and α_4 represent the elasticities and u_t represent the error term.

Referring to the studies presented by Sebri Maamar (2009), Lamia Jamel, Samir Maktouf (2017) and Nkengfack H., Kaffo F. (2015), we justify the choice of these variables and the expected signs as follows:

- Real GDP per capita: Gale and Mendez (1998) demonstrated in their model that an increase in GDP per capita would be linked to a decrease in the level of pollutant, whatever the level of income of the country. This result allows us to deduct that the GDP per capita demonstrates the impact of the level of development on the environment. The expected sign of α_1 is positive.
- The population: Azomahou et al. (2006) have shown that an increase of the population provokes an increase in food requirements, which cause overexploitation and reduction of natural resources and the increase in polluting emissions. The expected sign of α_3 is positive.
- The degree of openness of the economy: In their respective work, Grossman and Krueger (1994) and Halicioglu (2009) found that the coefficient sign of the variable trade openness α_4 varies according to the level of development of the countries. In developed countries, trade openness reduces environmental degradation, while the opposite effect is seen in developing countries. The economic theory asserts the existence of three kinds of effects of external openness on environmental quality, which are the scale effect (it affects negatively the quality of the environment), the technical effect (it affects positively the quality of the environment) and the effect of composition (has an ambiguous sign with the quality of the environment).

We will evaluate the regression equation (7) for the Algerian economy. A sample of annual data is used spanning the period 1970 to 2019. The data are taken from the World Bank (GDP, population density and commercial opening) and the Carbon Dioxide Information Analysis Center (CO_2).

3.2. The causality test

At this level of analysis, we will see if the emission of CO_2 causes the growth or if the growth that causes the emissions of CO_2. We will further see if there is a feedback relationship between the two? To answer this question, we will apply the Granger causality test, whose principle is defined as follows;

We will say X causes Y if the forecast based on knowledge of the common past of X and Y is better than the forecast based on knowledge of Y alone. We apply the non-causality tests based on the maximum likelihood statistic:

$$\xi = TC_{X \to Y} \tag{8}$$

Where T and $C_{X \to Y}$ represents the number of observations and the causality measure respectively.

Under the null hypothesis of non-causality, the equation (8) follows a Chi-square law at $\tau(T-\tau)p$ degree of freedom where τ is the number of imposed constraints. The decision rule is as follows:

If $\xi < \chi^2_{(\tau(T-\tau)p)}$, we accept the null hypothesis of an absence of causality.

If $\xi > \chi^2_{(\tau(T-\tau)p)}$, we reject the null hypothesis of an absence of causality.

Table 4

The Granger causality test

the null hypothesis	F statistique	p-value
$\log GDP_t$ ne cause pas $\log CO_{2t}$	13.11	0.0007
$\log CO_{2t}$ ne cause pas $\log GDP_t$	0.63	0.43
$\log GDP_t^2$ ne cause pas $\log CO_{2t}$	12,37	0,0009
$\log CO_{2t}$ ne cause pas $\log GDP_t^2$	0,76	0,38

From Table 4, we deduct that there is a causal relationship between GDP per capita and the emission of CO_2. It is also unidirectional relation, that expresses an effect of per capita GDP on the emissions of CO_2. We also found the same result for $\log GDP_t^2$. These results allow us to consider that taking environmental protection measures into account cannot have adverse effects on economic growth. Decision-makers are aware that the preservation and improvement of the environment could benefit the general interest in such a way that the private interest (pollution reduction research, treatment of polluting water by economic agents, etc.) could coincide with the general interest in preserving government spending (health spending, waste treatment, wastewater treatment, etc.).

3.3. The stationarity test.

The ADF stationarity test is applied in our case; the null hypothesis of non-stationarity is accepted for the level variables (CO_2, GDP per capita, GDP per capita squared and trade openness). On the other way, we see that the null hypothesis is rejected for the same variables in the first differences. The variables (CO_2, GDP per capita, GDP per capita squared and trade openness) are then integrated in order 1. On the other hand, we reject the null hypothesis of non-stationarity for the variable density of the population in level. Indeed, the population density variable is integrated of order 0. The variables of our model are not integrated of the same order, so that their orders of integration are less than two. What drove us to opt for the empirical study of this model by the ARDL (Autoregressive distributed lag model) approach introduced and developed by par Pesaran, Shin and Smith (2001). The choice of this approach is justified by the fact that:

- The sample size is reduced.

- The variables are stationary in order of integration less than two, not taking into account the constraint of the same order of integration.
- The endogeneity is not a problem.

The ARDL representation of equation 7 looks like this:

$$\Delta \log CO_{2t} = \lambda_1 \log GDP_t + \lambda_2 \log GDP_t^2 + \lambda_3 \log dPOP_t + \lambda_4 \log OPEN_t + \sum_{i=1}^{n} \delta_{1i} \Delta \log CO_{2t-i} + \sum_{i=1}^{n} \delta_{2i} \Delta \log GDP_{t-i} + \sum_{i=1}^{n} \delta_{3i} \Delta \log GDP_{t-i}^2 + \sum_{i=1}^{n} \delta_{4i} \Delta \log dPOP_{t-i} + \sum_{i=1}^{n} \delta_{5i} \Delta \log OPEN_{t-i} + \upsilon_t \quad (9)$$

Where Δ represents the first difference of the considered variables. It is derived from the following equation:

$$\log CO_{2t} = \sum_{i=1}^{n} \rho_{1i} \log CO_{2,t-i} + \sum_{i=1}^{n} \rho_{2i} \log GDP_{t-i} + \sum_{i=1}^{n} \rho_{3i} \log GDP_{i-i}^2 + \sum_{i=1}^{n} \rho_{4i} \log dPOP_{t-i} + \sum_{i=1}^{n} \rho_{5i} \log OPEN_{t-i} + \vartheta_t \quad (10)$$

3.4. The determination of delay number and the cointegration test

We used the criteria (Log L, LR, AIC, SC and HQ) to select the optimal number for the delays of VAR (P), with P varying from 0 to 4. The Schwarz criterion (SC) implies a delay of 2 (Table 5).

Table 5

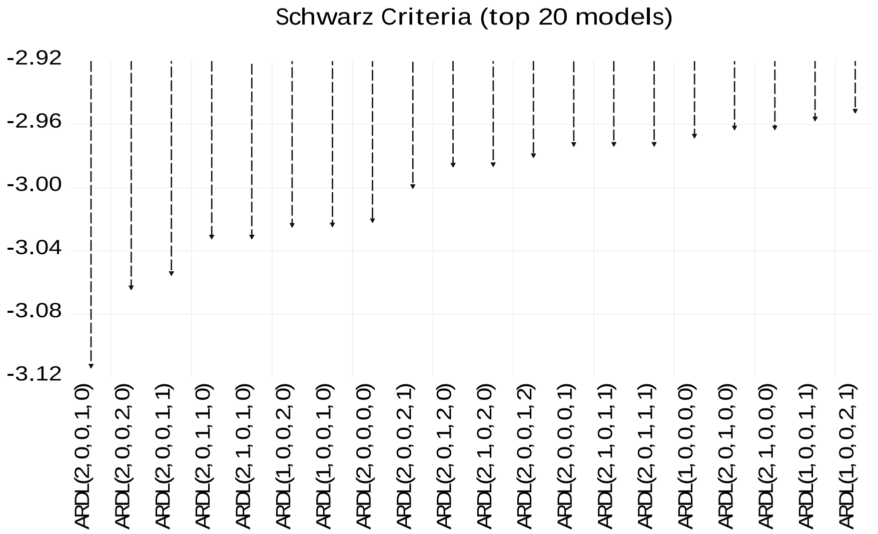
The choice of number of delay

Lag	LogL	LR	AIC	SC	HQ
0	112.4983	NA	-4.777703	-4.576963	-4.702869
1	588.0923	824.3629	-24.80410	-23.59966	-24.35510
2	703.4777	174.3601	-28.82123	-26.61309*	-27.99806
3	748.4787	58.00131	-29.71016	-26.49832	-28.51282
4	791.6284	46.02632*	-30.51682*	-26.30127	-28.94530*

We estimated twenty models (see Figure 2), based on the “Schwarz” criterion, our chosen optimal model is ARDL (2, 0, 0, 1, 0).

Chart 2

The twenty models estimated by ARDL



We used the "Bound test", which is based on the Fisher test, to assess the existence of a co-integrating relationship between the variables. From Table 6, the static F is 5.15, compared to critical values below and above the 5% significance level. The test statistic is greater than the upper limit (3.87). Therefore, we reject the null hypothesis of no cointegration and conclude that there is a long-term relationship between the model variables.

Table 6

The Bound's test

F-statistics	The Critical values		Meaning
	I_0	I_1	
5.15	2.372	3.32	10%
	2.823	3.872	5%
	3.845	5.15	1%

3.5. The estimation of the long-term and short-term equation

We have obtained an optimal ARDL model (2,0,0,1,0), so we can write it mathematically in the following form:

$$\log CO_{2t} = \rho_0 + \rho_1 \log CO_{2,t-1} + \rho_2 \log CO_{2,t-2} + \rho_3 \log GDP_t + \rho_4 \log GDP_t^2 + \rho_5 \log dPOP_t + \rho_6 \log dPOP_{t-1} + \rho_7 \log OPEN_t + \vartheta_t \quad (11)$$

The estimate of the coefficients of equation 11 is as follows:

$$\log CO_{2t} = -148,13 + 1,07 \log CO_{2,t-1} - 0,37 \log CO_{2,t-2} + 17_1 79 \log PIB_t - 0,53 \log PIB_t^2$$

$$(-3.14) \quad (7.05) \quad (-2.70) \quad (3,13) \quad (-3,11) \qquad (12)$$

$$+12,8 \log dPOP_t - 12,33 \log dPOP_{t-1} - 0,015 \log OUV_t$$

$$(2,72) \quad (-2,72) \quad (-0,30)$$

In the long term, we ask:

$$\log CO_{2t} = \log CO_{2t-1} = \log CO_{2t-2}$$

$$\log dPOP_t = \log dPOP_{t-1}$$

From equation 11, we deduct the long-term static equation:

$$\log CO_{2t} = -448,09 + 58,64 \log GDP_t - 1,77 \log GDP_t^2 + 1,54 \log dPOP_t - 0,05 \log OPEN_t$$

$$(-6.83) \quad (6.75) \quad (-6.69) \quad (4,78) \quad (-0,31) \qquad (13)$$

$\bar{R}^2 = 0,99$ F-Statistic $= 621,7$ P(F-Statistic) $= 0,01$ DW=2,03

The examination of the above results, using the Student test, show that the variable GDP per capita $\log GDP_t$, GDP per capita squared $\log GDP_t^2$ and the population density $\log dPOP_t$ are significant. However, the variable trade openness $\log OPEN_t$ is not significant. Moreover, the adjusted R-squared found indicates that 99% of the dispersion is explained by the regression model. The value of adjusted R-squared confirms that the different explanatory variables $\log GDP_t$, $\log GDP_t^2$, $\log dPOP_t$ and $\log OPEN_t$ actually have an influence on environmental quality (explained variable). This allows us to say that we have a good linear fit and strong explanatory power.

.The long-term static relationship of environmental quality is statistically acceptable, since P (F-Statistic) is less than 5%. We also find that the value of the Durbin-Watson statistic (DW) is equal to 2, this shows that the residuals of the static relationship are not autocorrelated.

The estimate of the coefficients of the short-term equation is as follows:

$$\Delta \log CO_{2t} = 0,37 \Delta \log CO_{2t-1} + 17,03 \Delta \log GDP_t - 0,51 \Delta \log GDP_t^2 + 12,64 \Delta \log dPOP_t$$

$$(3,63) \quad (3,70) \quad (-3,62) \quad (5,51)$$

$$-0,06 \Delta \log OPEN_t - 0,30 \text{ Eq}$$

$$(-1,12) \quad (-5,36)$$

3.6. The diagnostic test

We summarize the robustness tests in the following table: Estimation of the different tests.

Table 7

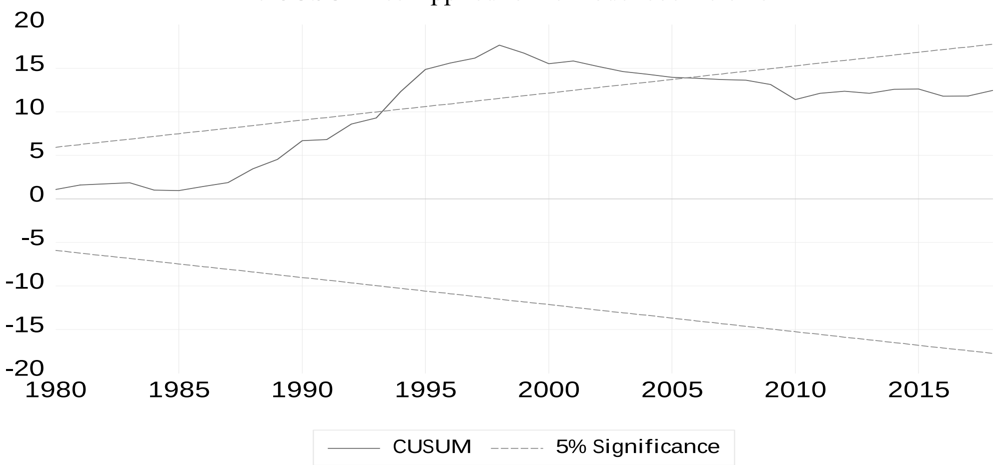
The robustness tests

Tests	F statistic calculated	P-value
Breusch-Godfrey Serial Correlation LM	2,07	0,13
Heteroskedasticity Test ARCH	0,97	0,32
Breusch-Pagan Godfrey	2,03	0,07
Ramsey Reset Test	3,52	0,06
Jarque-Bera	2,08	0,35

The residuals of our empirical model respect the four conditions: normality, stationarity, homoscedasticity and independence between the residuals (Table 7).

Chart 3

The CUSUM test applied to the model coefficients



These tests indicate that our model is statistically valid. To study the overall stability of our relationship, several tests can be used: the recursive residuals, CUSUM squares and CUSUM tests. In our case of treatment, we use this last test (CUSUM).

We observe in chart 3 that the CUSUM is outside the corridor. About this test, we confirm that the relationship is unstable. From the statistical study which we carried out, we can affirm that the model:

$$\log CO_{2t} = -448,09 + 58,64 \log GDP_t - 1,77 \log GDP_t^2 + 1,54 \log dPOP_t - 0,05 \log OPEN_t$$

is generally acceptable as long as the explanatory power of this model is very high (it is 99%), so that the conclusions drawn from this work are convincing.

4. The Interpretation of the Results

The GDP per capita variable $\log GDP_t$ exhibits a positive impact on environmental quality, an increase of 1% of GDP per capita leads to a 58.6% increase in environmental quality and a decrease in the level of air pollution. The long-term elasticity (58.6) is important. Findings show that the positive relationship which we have found between air pollution and economic growth. This link is compatible with the content of economic theory in this field. The positive effect between economic growth and emissions of the CO_2 indicates that the country would be in the ascending phase of the Environmental Kuznets Curve. Our result agrees with those found by Gale and Mendez (1998). We found a negative sign for the variable $\log GDP_t^2$, this shows an increase of 1% of GDP per capita squared $\log GDP_t^2$ will lead to a decrease in the emission of the CO2 in (1,77%). The signs of the coefficients associated with GDP per capita $\log GDP_t$ and GDP per capita squared $\log PIB_t^2$ are expected signs and consistent with economic theory and the existence of an EKC in the case of Algeria. The population has a positive and significant impact on the emissions of the CO_2, a 1% increase in the population allows a 1.54% increase in CO_2. This result, a positive relationship between population and the emissions of CO_2 reflets the basic economic theory which postulates that population reduction would be effective for environmental quality. Our result is consistent with that of Azomahou et al. (2006). Trade openness, $\log OPEN_t$ exhibits a negative and insignificant effect on emissions of the CO_2, an increase of one unit in the openness would result in an insignificant decrease in emissions of CO_2 in 0.05%. This negative relationship displayed between the two variables is consistent with the argument of economic theory. This means that the trade liberalization stimulates the migration of polluting companies from developed countries to invest in Algeria, even if it is more demanding and uncompromising in terms of environmental protection. Their location is also justified by other motivations, which we can explain by the rate of profit, a large internal market with strong potential of growth, etc. The negative sign of the coefficient of trade openness can be explained by the fact that free trade has accelerated economic activity by stimulating the volume of transactions, consumption and domestic production while creating more wealth, has been accommodated with the measures to preserve environmental quality. Our results are consistent with those of Gale and Mendez (1998). However, our results are contradictory to those of Grossman and Krueger (1994) and Halicioglu (2009), who found, trade openness increases environmental degradation in developing countries.

In the facts, faced with increasingly strict regulations, companies in industrialized countries are sometimes are interested to relocate their dangerous activities in the countries of the world where environmental protection and public health measures are less restrictive as well as occupational safety and environmental protection are not closely monitored by the government authorities. The examination of the short-term relationship lets us admit, that the coefficient associated with the restoring force, is negative (-0.30), but it is significantly different from zero at the statistical threshold of 5%. Those results admit the existence of a long-term stable relationship between the emissions of CO_2 and the different explanatory variables. As this coefficient is less than unity, we can assert that the adjustment period indicates that the mismatches between the long term and the short term are absorbed in less than a year. From these results, we can assert that there is an error correction mechanism, which indicates the desire to seek a convergence of the trajectory for the series of CO_2 emissions. On another side, others variables show a negative impact on emissions of CO_2 as, the GDP per capita squared and the trade openness. We found that the EKC is also verified in the short term for the case of Algeria because the signs of the coefficients associated with $\Delta \log GDP_t$ and $\Delta \log GDP_t^2$ show positive and negative signs, respectively.

Concluding Remarks

The aim of our paper is to validate the existence of an environmental Kuznets curve (EKC) but also to study the influence of international trade and the population on emissions of CO_2 in Algeria during the period 1970 to 2019. To carry out this study, we used a polynomial model of degree two, the three economic specificities (linear, semi-linear and log-linear). We observed the stationarity, the cointegration between the variables and the estimation of the model by the Johansen approach. We found that the coefficients of the three models are significant except for the semi-linear model and the existence of the EKC for the three models. We have extended the log-linear model, which was retained by "Schwarz criterion" by adding two explanatory variables (international trade and population). We applied the ARDL approach for the boundary tests or the cointegration test of Pesaran et al. (2001) to this extended model.

With this model, we found that the EKC is verified in the long term and in the short term and that all the coefficients of the long-term and short-term variables are significant except for the coefficient of the trade openness variable, however all the signs of these coefficients are explained by the economic theory. The estimation of the coefficients of the static equation in the long and short term allows us to assert that the GDP per capita, the GDP per capita squared and the population have a positive impact on emissions of the CO_2 in Algeria, but conversely, trade openness has a negative effect on emissions of the CO_2. The moving towards further free trade to create more wealth must be accompanied with great severity in monitoring the quality of the environment by resorting a various forms of regulation (an environmental tax properly-implemented, change of model industrial by investing in renewable energies etc.) which could be imposed on investors, contradicts the hypothesis of the deterioration of the environmental climate of developing countries showing an evolution of the growth-pollution relationship. These explanations find their basis in economic theory and agree with the results of Gale and Mendez (1998). However, this result is contradictory to those of Grossman and Krueger (1994) and Halicioglu (2009). We found a long-term stable relationship between the emissions of the CO_2 . The various explanatory variables (the return force coefficient is negative and significant) as well as a unidirectional causal relationship that goes from GDP per capita to the emission of the CO_2. The quality of the estimate of our model is good, an interesting one with regard to the Fisher statistic, the coefficient of determination and the Jarque-Bera statistic.

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