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Tracing the path: testing the environmental Kuznets Curve in Algeria using ARDL bounds testing

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Abstract. *This study aims to test hypothesis of Environmental Kuznets Curve (EKC) in Algeria using the Autoregressive Distributed Lag (ARDL) bounds testing methodology. The objectives include examining the long-term relationship between economic growth and* CO_2 *emissions, investigating the impact of structural breaks on this relationship's stability, and offering policy recommendations informed by the findings. The research utilizes annual data related* CO_2 *emissions and GDP per capita from 1962 to 2014 in Algeria. The data are analyzed through the ARDL bounds test to ascertain the existence of a long-term equilibrium relationship. The study incorporates structural breaks to account for potential changes in the economic-environmental relationship over time. The findings confirm the presence of an EKC pattern in Algeria, showing a reverse U-shaped nexus between economic growth and* CO_2 *emissions. The Inclusion of structural breaks in the analysis led to the stability of the model compared to the case of their absence that led to a variability in the model coefficients. Thus, it provides a more accurate and reliable understanding of this relationship. The threshold at which economic growth starts to decrease* CO_2 *emissions, is identified at a GDP per capita of approximately $4125.58 (constant 2010 $), which Algeria reached in 2005. Furthermore, if disequilibrium between* CO_2 *emissions and economic growth is occurred due to a possible short-term shock, the return toward the steady state requires three years approximately. While the results validate the EKC hypothesis for Algeria, the paper is limited to the period from 1962 to 2014 and may not capture more recent economic and environmental changes. Furthermore, the study aims to enrich the EKC literature in Algeria, which is characterized by scarcity, by using the recent ARDL bounds test methodology and addressing basic assumptions that were violated in previous studies. This study highlights the importance of considering structural breaks in environmental-economic analyses to avoid biased estimations and incorrect policy recommendations. Future research should explore additional determinants of* CO_2 *emissions, such as biofuel use, advanced technologies, environmental awareness, urbanization, foreign direct investment, and employment. Policymakers should promote clean energy and sustainable economic practices to ensure continued environmental improvements alongside economic growth.*

Keywords: Environmental Kuznets Curve, CO_2 emissions, cointegration; ARDL bounds test, structural changes.

JEL Classification: C22, C51, C87, O11.

1. Introduction

Global warming, marked by rising global temperatures and disrupted climate patterns, presents a complex challenge for scientists and policymakers. This phenomenon is mainly caused by human activities, such as combustion of fossil fuels, industrial processes, agricultural activities, and deforestation. A significant result of global warming is its negative impact on air quality due to the excessive concentration of carbon dioxide emissions (CO_2) in the atmosphere. As a result, the intricate relationship between economic activities and the environment gives rise to global warming.

The nexus between the environment and economic activity has garnered significant attention from researchers and decision-makers. The relationship between the environment and economic activity has garnered significant attention from researchers and decision-makers. However, what has surprised and was unexpected is the observation of having improved air quality and reduced air pollution at high levels of economic growth, after surpassing critical income levels. This phenomenon, known as the environmental Kuznets curve (EKC hereafter) and has garnered significant attention. Kuznets found that inequality initially increases at medium income, then decreases, following a bell curve that now bears his name. This hypothesis suggests that during the early stages of any development model, Economic Growth (E.G) may lead to increased pollution and environmental deterioration as countries favourite economic progress over environmental concerns. However, as countries achieve higher levels of affluence and industrialization, that allow to shift toward environmental conservation, conducting to reduced pollution and improved environmental quality.

The works of Shafik & Bandyopadhyay (1992) and Panayotou (1994), building upon the research by Grossman & Krueger (1991), that is what form the foundation of the EKC. These studies employ water pollution, CO_2 emissions, and deforestation as indicators of pollution, and GDP per capita as a measure of economic growth. Over the past two decades, the examination of the EKC has attracted significant scholarly attention, as evidenced by the growing body of literature on the subject.

Understanding the EKC hypothesis is a crucial requested ground for policymakers and environmental advocates to concept effective policies that harmonize economic growth with environmental sustainability.

The present research aims to examine hypothesis of (EKC) through the using of (ARDL) bounds testing approach, specifically within Algerian context. The objectives are to test the long-term relationship between Economic Growth (E.G) and CO_2 Emissions in Algeria with an explicit consideration of structural breaks on the stability of this relation, following by policy recommendations based on the findings.

The study addresses the following key questions:

Does the validation of the hypothesis of EKC depend on the inclusion of structural changes in the research model?

What is the impact of structural change on the stability of the relation between Economic Growth and Environment?

A significant methodological gap in previous research is the omission of structural breaks in the analysis. Ignoring structural breaks can lead to biased estimations and incorrect inferences about the relationship between economic growth and environmental degradation. as falsificates the reliability of recommendations deducted from such researches, besides they do not fully reflect the dynamic nature of the economic-environmental relationship in the Algeria context.

The research contributes to the present body of literatures using the ARDL bounds testing methodology with an explicit consideration of structural breaks; by merging structural breaks into the model and employing an updated and comprehensive dataset spanning from 1962 to 2014, the study's approach offers a reliable and more robust examination of the (EKC) hypothesis in Algeria.

Awaiting results show that the nexus between Economic Growth (E.G) and CO_2 Emissions in the Algerian area may be affected by structural changes. The presence of a positive coefficient for GDP and a negative coefficient for GDP squared in the long run could confirm the existence of the EKC, focusing on the significance of considering structural breaks in such EKC examination.

2. Literature review

The EKC hypothesis supposes a reversed U-shaped relationship between environmental degradation and income; it suggests that pollution levels initially increase with economic development, reaching a peak and then declining as income increases. (Shahbaz & Sinha, 2019). This hypothesis has received substantial scholarly attention during the last decades, and researchers have uncovered its carrying out in different contexts, numerous seminal works have laid the groundwork for understanding this phenomenon (Grossman & Krueger, 1991; Panayotou, 1994; Shafik & Bandyopadhyay, 1992), these works shown that at higher income levels, societies favorite environmental quality, conducting to increased pollution and improved air quality (Purcel, 2020). On this basis, the theoretical framework of the hypothesis of (EKC) includes several mechanisms, at the early stages, Economic Growth leads to more pollution due to increased production and consumption, known as the scale effect. As economies develop, the industrial structure shifts from highly polluting industries to cleaner, service-oriented sectors, known as the composition effect. Furthermore, technological progress and higher incomes enable the adoption of cleaner technologies and stricter environmental regulations, known as the technical effect.

A large body of empirical work has examined the EKC hypothesis across various economies and pollutants, for example, (Dinda, 2004) has provided a comprehensive review of empirical research, confirming the existence of (EKC) for several environmental indicators, encompassing CO_2 emissions. However, the results are not uniform and the presence of EKC often depends on specific country characteristics and the type of pollutant considered. Furthermore, (Pao & Tsai, 2011) conducted a study using annual data on GDP and CO_2 emissions in the Brazilian context to examine the validity of(EKC), using the cointegration method to test the ARDL bounds, their results confirmed the existence of the hypothesis of (EKC). In contrast, (Saboori et al., 2012) examined Malaysian data on CO_2, Economic Growth (E.G), and Energy Consumption (E.C), they concluded that EKC is a long-run phenomenon as their examination failed to identify short-run EKC using different cointegration methods. They further identified a bi-directional causality between economic growth and carbon dioxide emissions. Likewise, in Pakistani area, (Nasir & Ur Rehman, 2011) investigated the relationship between CO_2 emissions, economic growth, Foreign Trade and Energy, they have confirmed the presence of long-run EKC through the applying of Johansen cointegration,

The omission of structural breaks in analyses can lead to biased estimations and inaccurate policy recommendations. Studies by (Bai & Perron, 2003; Perron, 1989) highlighted the importance of accounting for such breaks to avoid spurious results. Hence, incorporating structural breaks into the models is decisive for a more robust examination of the (EKC) hypothesis (Sinha & Shahbaz, 2018), the ARDL bounds testing technique, particularly, captures both the short-run dynamics and the long-run equilibrium in the relationship between the variables, with including structural breaks, the modelling by ARDL approach becomes more robust and truthful.

Works by (Osabuohien et al., 2014) on different African states and by (Fan & Zheng, 2013; Hao et al., 2016) on Chinese provinces illustrate the common interest in testing the (EKC) assumption across various regions. These works underscore the significant of understanding the dynamics of Economic Growth and environmental sustainability, in particular in developing and transitional economies, furthermore, the work of (Van Alstine & Neumayer, 2008) underlined the need to update methodologies, such as the ARDL bounds testing method to improve the accuracy of (EKC) estimations.

The implementation of the assumption of EKC in Algeria involves examining the unique economic and environmental context of the country. Algeria's dependence on its fossil energy resources, coupled with its economic development trajectory, makes it an interesting case study for testing the EKC hypothesis, nonetheless, few studies have examined the EKC hypothesis in Algeria. (Bouznit & Pablo-Romero, 2016) conducted a study utilizing annual data from 1970 to 2010 on various variables including CO_2 emissions, GDP, energy consumption, electricity consumption, imports, and exports. They employed the ARDL bounds test cointegration method with breakpoints to examine the EKC hypothesis, their findings indicated that GDP, energy consumption, electricity consumption, and imports have positive impacts on CO_2 emissions, whereas exports have a negative impact on CO_2 emissions. The presence of a positive coefficient for GDP and a negative coefficient for GDP squared in the long run confirms the existence of the EKC. To enhance energy efficiency and regulate energy demand, the authors suggested the promotion of energy efficiency measures and reduction of energy subsidies. Additionally, (Latifa et al., 2014) aimed to test the presence of the EKC utilizing the ARDL bounds test cointegration methodology and the vector error correction model (VECM)-based causality test. The study revealed cointegration between CO_2 emissions per capita and GDP per capita, confirming the EKC hypothesis. The causality test demonstrated unidirectional causality from income to CO_2 emissions - both in the short and long run. Similar results were found by Touitou, (2021) by using the VECM method for economic growth and environmental degradation, utilizing three environmental indicators (CO_2, SO_2, and NOx) for the 1980-2017 period.

Controversy, Lacheheb et al. (2015) adopted the (Narayan & Narayan, 2010) approach to examine the EKC assumption by comparing short-run income and long-run one elasticities during 1971-2009. The authors examined the relationship between GDP per capita, gross fixed capital formation, imports, exports, population and CO_2 emissions from three sources: CO_2 from solid fuel consumption, CO_2 from liquid fuel consumption, and CO_2 from electricity/heat consumption, using the ARDL bounds testing method. They found that both income and population had a significant impact on CO_2 emissions, particularly CO_2 from solid fuel consumption and CO_2 from electricity/heat production. However, only population had a significant impact on CO2 emissions from liquid fuel consumption. In addition, they found no evidence supporting the EKC hypothesis in Algeria and suggested that Algeria should urgently transition towards a service-intensive economy and adopt renewable energy sources to mitigate environmental degradation and stimulate economic growth. Similarly, (Layachi, 2019) has conducted a study that has supported the absence of the EKC in Algeria. The study examined the impact of three energy source prices (oil, natural gas, and fuel oil) and GDP on CO_2 emissions using the ARDL bounds test cointegration method. The study revealed that GDP had a positive and significant impact on CO_2 emissions, while all energy prices (oil, fuel oil, and natural gas) had a negative and significant impact on CO_2 emissions.

Research Gap

The literature on the EKC hypothesis provides a rich foundation for investigating the relationship between per capita income and environmental quality. By addressing methodological gaps, such as the omission of structural breaks, researchers can contribute to a more nuanced understanding of how economic development impacts the environment. Ignoring structural breaks can lead to biased estimations and incorrect inferences about the relationship between economic growth and environmental degradation, potentially resulting in inaccurate conclusions regarding the validity of the EKC hypothesis.

In the Algerian case, most of the studies did not take structural changes into account when modeling EKC hypothesis. Ignoring structural changes in the model can lead to spurious relationship between variables, inaccurate forecasting and misleading policy recommendations (Hansen, 2001; McNown et al., 2018). This oversight undermines the reliability of policy recommendations derived from such studies, as they do not fully capture the dynamic nature of the economic-environmental relationship in Algeria. By considering structural changes and utilizing advanced econometric techniques, researchers can enhance the robustness of their analyses and better inform policy decisions. For these reasons, our approach provides a more robust and reliable analysis of the EKC hypothesis in Algeria.

2. Data and Methods

2.1. Data source

For this study, we use annual data on carbon dioxide (CO_2) emissions per capita (measured in metric tons) and GDP per capita (measured in constant 2010 U.S dollars). These data are derived from the World Bank database (WDI) for the period 1962-2014. The variables are transformed into logarithmic form.

2.2. Model specification

In the literature, the general form of the EKC hypothesis is typically formulated as follows:

$$lnE = f\ (lnY, (lnY)^2, lnZ)\ \ldots\ldots\ldots \qquad \text{(Eq.1)}$$

Where, ln: the natural logarithm, E: represents an indicator of environmental quality, and Y: represents gross domestic product per capita, and Z includes other variables that can influence environmental deterioration.

Among greenhouse gases, CO_2 is the main component (IEA, 2018). For this reason, most studies regarding the EKC hypothesis use CO_2 emissions as an indicator of environmental pollution, as adopted in this study.

To measure the direct and indirect effects of economic growth on CO_2 emissions, we employed the reduced form of the EKC equation(Eq.2) as outlined by List & Gallet, (1999):

$$lnCO2_t = \beta_0 + \beta_1 lnY_t + \beta_2 [lnY_t]^2 + \epsilon_t\ \ldots\ldots\ldots \qquad \text{(Eq.2)}$$

Where, CO_2: carbon dioxide emissions per capita to measure environmental pollution, Y: GDP per capita, ϵ: the random error term, t: time index from 1962 to 2014, $\beta_i, i = 0,1,2$: estimated coefficients. The quadratic term $(LnY)^2$ is included in the equation to capture the inverse U-shape of the EKC curve. If $\beta_1 > 0\ and\ \beta_2 < 0$, the curve takes an inverse U shape, so the EKC hypothesis is valid. If this were the case, the inflection point can be calculated as follows: $Y^* = exp\ (-\frac{\beta_1}{2\beta_2})$.

2.3. ARDL Bounds test for cointegration

To examine the existence of a long-run equilibrium relationship between CO_2 per capita emissions and GDP per capita, we adopt the ARDL bounds test of Pesaran et al., (2001). This cointegration method:

- is flexible regarding the integration order of variables: the ARDL bounds test procedure can be applied to variables that are integrated of order zero I(0), order one I(1), or mixture of both, but not order two I(2). This flexibility enhances the accuracy of the estimation process, especially when analysing complex macroeconomic data.
- incorporates both short-term and long-term relationships into a single equation known as the unrestricted error correction model (UECM) without losing long-term information.
- the optimal selection of the lag for the UECM avoids both autocorrelation and endogeneity problems.

The ARDL representation under the UECM for the reduced form of the EKC formulated as follows:

$$\Delta lnCO2_t = \alpha_0 + \sum_{i=1}^{p1} \alpha_{1i} \Delta lnCO2_{t-i} + \sum_{i=0}^{p2} \alpha_{2i} \Delta\ lnY_{t-i} + \sum_{i=0}^{p3} \alpha_{3i} \Delta [lnY_{t-i}]^2 + \phi_1 lnCO2_{t-1} + \phi_2 lnY_{t-1} + \phi_3 [lnY_{t-1}]^2 + \omega DM_t + \nu_t \ldots\ldots \quad \text{(Eq.3)}$$

α_0: constant term, $(\alpha_{1i}, \alpha_{2i}, \alpha_{3i})$; for i=1, 2,3: short-run coefficients, $\phi_i; for\ i = 1,2,3$: long-run coefficients. DM: dummy variable that represents structural changes, Δ:first difference operator, (p1, p2, p3): the optimal lag lenght for lagged variables $\Delta lnCO2$, ΔlnY and $\Delta [lnY]^2$ respectively based on Schwarz Information criteria (SIC), t: time index, ν_t: random error term.

To explore the existence of cointegration relationships between variables, Pesaran et al., (2001) propose testing the following null hypothesis of no cointegration:

$H_0: \phi_1 = \phi_2 = \phi_3 = 0$

against the alternative hypothesis of cointegration:

$H_1: \phi_1 \neq \phi_2 \neq \phi_3 \neq 0$

For this, we perform the F-Wald test and compare the F-statistic to the critical values tabulated by (Pesaran et al., 2001). They report two sets of critical values: lower bounds and upper bounds. Lower bounds assume that the variables are I(0), while upper bounds correspond to I(1).

If : F-statistic < I(0), we cannot reject H0 ⟶ no cointegration:

if : F-statistic > I(1), we reject H0 ⟶ cointegration;

if : I(0) ≤ F-statistic ≤ I(1) ⟶ inconclusive test.

However, the critical values of (Pesaran et al., 2001) are inapplicable to small samples as our sample(52 observations). For this, we use the critical values introduced by (Narayan, 2005) for small sample sizes spanning from 30 to 80 observations.

When the cointegration test indicates the existence of a cointegration relationship, we can derive the long and short run equations.

2.3.1. Long run equation

Equation2 (Eq.2) represents the long-run equation, also called the cointegration equation.

2.3.2. Short run equation

The short-run equation-called the error correction model-is formulated as follows:

$$\Delta lnCO2_t = \varphi_0 + \sum_{i=1}^{p1} \varphi_{1i} \Delta lnCO2_{t-i} + \sum_{i=0}^{p2} \varphi_{2i} \Delta\ lnY_{t-i} + \sum_{i=0}^{p3} \varphi_{3i} \Delta [lnY_{t-i}]^2 + \delta ECT_{t-1} + \gamma DM_t + e_t \ldots\ldots \quad \text{(Eq.4)}$$

Where, ECT_{t-1} indicates error correction term lagged one period. The ECT is the residuals of estimated long-run relationship (Eq.4). Hence, $ECT_t = \epsilon_t$ is the speed of adjustment towards the long-run equilibrium. In order to confirm the long run relationship among variables, the ECT coefficient should be negative and statistically significant (Banerjee et al., 1998).

To ensure the reliability of the model, it is important to verify the residual diagnostic tests. These tests are the normality test, the Breusch-Godfrey test for autocorrelation, and the Breusch-Pagan-Godfrey test for heteroscedasticity. Furthermore, to ensure the stability of the estimated coefficients over the study period, the cumulative sum (CUSUM) and cumulative sum squared (CUSUMSQ) tests of recursive residuals are used.

3. Empirical results and discussion

The starting point of the cointegration analysis is the examination of stationarity properties of the time series under study to ascertain its order of integration.

3.1. Stationarity analysis

As a first step, we used conventional unit root tests such as the augmented Dickey-Fuller test (ADF test) and the Phillips-Perron test (PP test). The results of these tests are summarized in Table 1. The ADF test indicated that the LnCO2 and LnY series are significantly stationary in their first difference at the 1% level. While the PP test indicated the stationarity of the series in their levels. When the results of the ADF and PP tests conflict for low-frequency data, such as annual data, we prioritize the PP test due to its higher test power (Maddala & Kim, 1999) Therefore, the time series of the study are integrated of order zero, I(0).

Table 1. *Conventional unit root test results*

	ADF test				PP test				I(d)
	Level		1st difference		Level		1st difference		
	trend & intercept	intercept	trend & intercept	intercept	trend & intercept	intercept	trend & intercept	Inter-cept	
$lnCO2_t$	-1,91 (0,63)	-2,43 (0,13)	-8,44 (0,00)	-7,97 (0,00)	-1,796 (0,69)	-2,78 (0,068)			I(0)
lnY_t	-1,59 (0,78)	-1,48 (0,53)	-9,9 (0,00)	-9,92 (0,00)	-3,54 (0,045)	-3,39 (0,016)			I(0)
$[lnY_t]^2$	-3,93 (0,018)	-1,39 (0,58)	-	-	-3,33 (0,072)	-3,26 (0,02)			I(0)

Notes: Values in parentheses represent p-values.
Source: Own Elaboration based on *Eviews 10 output.*

However, when a possible structural breakpoint may occur in the series, the usual unit root tests can lead to biased estimates, because these tests ignore the existence of structural breakpoints when they exist. To address this issue, we apply a unit root test that considers a breakpoint with gradual changes based on the minimum Dickey-Fuller t value to determine the breakpoint. The results are provided in Table 2.

The results indicate that evidence of unit root was found for the $lnCO2_t$ series when considering a structural break in the intercept (Model A), and the break occurred in 1969. For the lnY_t and $[lnY_t]^2$ series, the test indicates that they are significantly stationary at their levels and that the break is located in 1975.

Table 2. *Unit root tests with breakpoint*

	Model-type	Level		1st difference		I(d)
		t-statistic	break date	t-statistic	break date	
$\boldsymbol{lnCO2_t}$	Model A	4,587	1969	9,445***	1973	I(1)
$\boldsymbol{lnY_t}$	Model C	5,195***	1975			I(0)
$[\boldsymbol{lnY_t}]^2$	Model C	5,118***	1975			I(0)

Notes: *** signifies 5% level of significance, Model A: with constant, Model C: with trend.
Source: Own Elaboration based on *Eviews 10 output.*

Generally, unit root tests indicate that there is a mixture of I(1) and I(0) variables, but not I(2). Therefore, the ARDL approach of cointegration is applicable.

3.2. Cointegration analysis:

As demonstrated by the unit root tests in the previous sub-section, the dependent variable is stationary at its first difference. This is the condition that (Pesaran et al., 2001) assumed to avoid the degenerate case. As outlined by (Pesaran et al., 2001), degenerate case means absence of cointegration. The ARDL bounds test results are provided in Table 3.

Table 3. *ARDL bouds test results*

Optimal lag lenght:	(1, 0, 0)		
F-statistic =	4,77		
Critical values (Narayan, 2005):			
	1%	5%	10%
Lower bounds I(0)	4,61	3,303	2,748
Upper bounds I(1)	5,563	4,1	3,495

Notes: Lag selection is based on SBC. Critical values are obtained from Narayan (2005), Tables, case II: restricted constant and no trend.
Source: Own Elaboration based on *Eviews 10.*

The optimal lag length selection based on the Schwarz Bayesian criterion (SBC) is (1, 0, 0) for the variables $LnCO_2$, LnY, and $(LnY)^2$, respectively. Because the sample size of our study is small (52 observations), we use the critical values of (Narayan, 2005) for testing the bounds of the F statistic rather than (Pesaran et al., 2001). The results indicate that the F statistic is greater than I(1) bounds at the 5% significance level, which implies the existence of cointegration between the variables $LnCO_2$, LnY, and $(LnY)^2$.

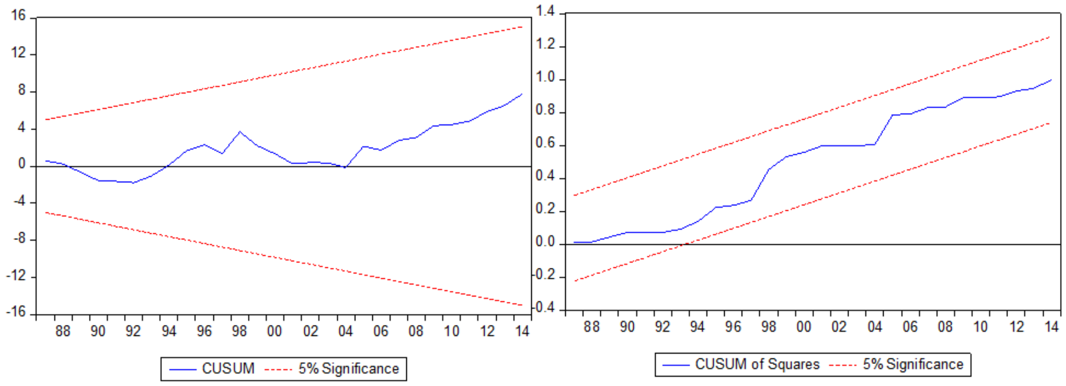
Table 4. *Diagnostic tests for conditional error correction model (Eq.3)*

Diagnostic test	Null Hypothesis	Statistic	Decision
Normality test	H0: Normality	JB = 0,74 (0,69)	Accept H0
Breush-Godfrey serial correlation test	H0: No autocorrelation	LM = 0,625 (0,73)	Accept H0
Breush-Pagan-Godfrey test	H0: Homoskedasticity	LM = 6,7 (0,152)	Accept H0

Notes: Values in parentheses represent p-values.
Source: Own Elaboration based on Eviews 10output.

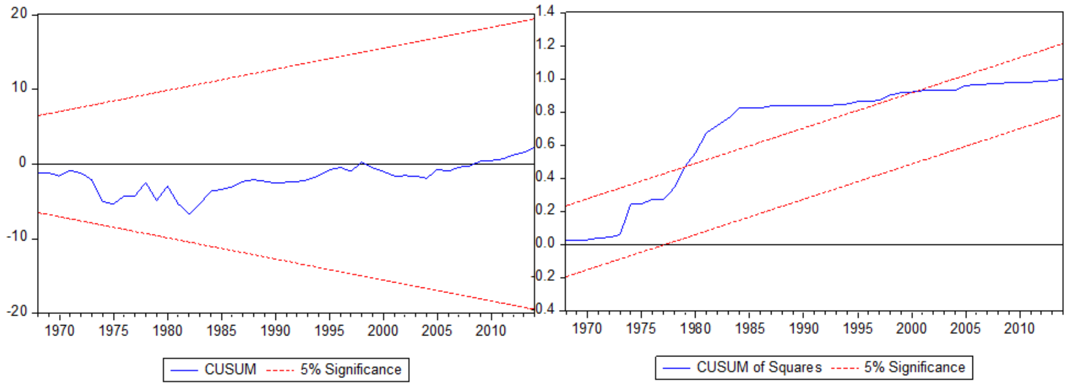
The results of the diagnostic tests of the residuals of the UECM model (Eq. 3) are presented in Table 4. These results indicate that the estimated model passes the diagnostic tests for normality, autocorrelation, and heteroskedasticity. Thus, the estimated model is accepted. Additionally, Figure 2 shows that the CUSUM and CUSUMSQ tests are within the 5% critical limits, indicating the stability of the UECM model coefficients over the study period. Compared with Figure 3, in which the model coefficients appear to be unstable, the inclusion of structural changes led to model stability. Therefore, the model is considered reliable and flawless for policy-related purposes.

Figure 2. *Plot of Cumulative Sum (CUSUM) and Cumulative Sum of Squares(CUSUM of Squares) of Recursive Residuals with structural breakpoint.*



Source: *Eviews 10 output* and our elaboration.

Figure 3. *Plot of Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUM of Squares) of Recursive Residuals without structural breakpoint.*



Source: *Eviews 10 output* and our elaboration.

3.2.1. Long run estimations

Once the cointegration relationship between the variables has been confirmed, the next step involves estimating the long-term (Eq. 2) and the short-term (Eq. 4) equations. Table 5 illustrates the estimation results of Eq. 2 and Eq. 4. The long-term estimates indicate that the coefficients of GDP per capita and GDP per capita squared have significant values at the 1% level with positive and negative signs, respectively, thus confirming the presence of the EKC hypothesis in Algeria during the period 1962-2014. By using the long-term equation (Eq. 2), we construct the graph in Fig. 4. It is clear from this graph that an increase in GDP per capita initially leads to an increase in per capita CO_2 emissions up to a certain threshold of GDP per capita, which constitutes the turning point. After this point, this relationship reverses and a further increase in GDP per capita leads to a decrease in per capita CO_2 emissions, resulting in an inverted U-shaped graph. This result is consistent with research carried out in Algeria by (Bouznit & Pablo-Romero, 2016), (Latifa et al., 2014), and (Touitou, 2021), in Qatar by (Mrabet & Alsamara, 2017) , in China and India by (Adebola Solarin et al., 2017) , in France by (Ang, 2007), in Brazil by (Pao & Tsai, 2011), in 11 Commonwealth countries by (Apergis & Payne, 2010), in Malaysia by (Saboori et al., 2012), in South Africa by (Kohler, 2013), in Canada by (Hamit-Haggar, 2012), in Romania by (Shahbaz et al., 2013), and in Spain by (Esteve & Tamarit, 2012). On the other hand, these results differ from those obtained in Algeria by (Lacheheb et al., 2015b) and (Layachi, 2019), in Tunisia by (Farhani & Ozturk, 2015) , in Saudi Arabia by (Alshehry & Belloumi, 2017) , in China by (Wang et al., 2011) , in Turkey by (Acaravci & Ozturk, 2010) , and in Russia by (Pao et al., 2011).

Although there is similarity between this study and (Bouznit & Pablo-Romero, 2016) in terms of the methodology used and the results obtained, findings of Bouznit & Pablo-Romero (2016) are questionable because they violated one of the basic assumptions of the ARDL approach of (Pesaran et al., 2001), which is the I(1) dependent variable. Bouznit & Pablo-Romero (2016) study indicated that the dependent variable is I(0), while in this study there is evidence that the dependent variable is I(1), as Pesaran et al. (2001) recommended, to avoid falling into a degenerate case that implies absence of cointegration.

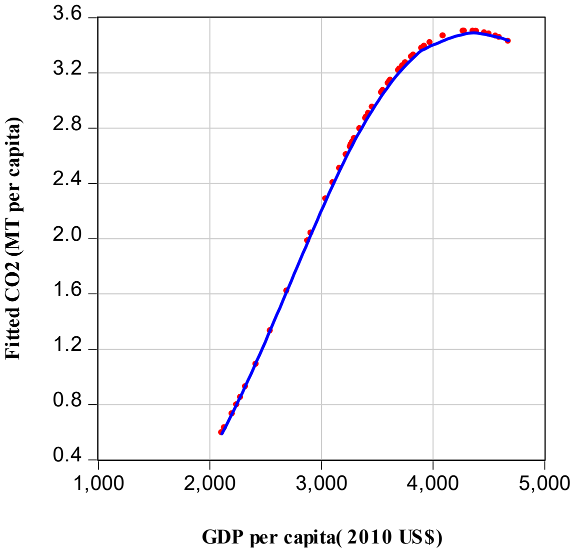
Table 5. *ARDL long run and short run results.*

Variable	Coefficient	t-statistic
Long-run(Eq.2)		
LnY_t	65,23	3,46***
$(LnY_t)^2$	-3,914	-3,35***
β_0	-270,57	-3,56***
	Short-run(Eq.4)	
DM	0,0017	0,033
ECT_{t-1}	-0,35	-4,5***
$DW = 2{,}15$; $R^2 = 0{,}24$		

Notes: *** indicates 1% level of significance, DW: Durbin-Watson statistic, R^2: coefficient of détermination.
Source: Eviews 10 output.

The income turning point, that is, the level of per capita income where per capita CO_2 emissions begin to decline, has been estimated at approximately $4125.58 (in constant 2010 $). Algeria reached this level of GDP per capita in 2005 and has since succeeded in reducing its CO_2 emissions.

Figure 4. *Plot of fitted EKC in Algeria during the period 1962-2014*



Source: Own Elaboration.

3.2.2. Short run estimations

The results obtained from the short term estimates revealed that GDP per capita has no effect on CO_2 emissions per capita. This confirms the idea that the EKC is a long-term phenomenon, rather than a short-term phenomenon, and that it is indeed applicable in Algeria. Since growth and development are long-term processes, it follows that the period we adopted in this study can be considered a long-term period and sufficient to reveal the phenomenon of the EKC. This statement is consistent with the findings of (Dinda, 2004), (Nasir & Ur Rehman, 2011), (Saboori & Sulaiman, 2013), and (Ahmad et al., 2017), who all argue that the EKC is a long-term phenomenon and its validity needs to be assessed over a long period of time. The dummy variable, which represents structural changes, affects CO_2 emissions significantly in the short term. The most influential structural changes occurred in Algeria in the early 1980s. The break of the early 1980s coincided with the 1986 oil crisis that led to a recession in the country. Our analysis revealed that the speed of adjustment, as measured by the ECT, is negative and significant at 1% level. The ECT coefficient (0.35) confirms that in the possible short-term shock, the model would move towards the long-term trajectory at a yearly rate of adjustment of 35%. This implies that the adjustment takes about three years to restore the long-term equilibrium level.

4. Conclusion

This study had two goals. Firstly, we test the validity of the EKC hypothesis in Algeria. Secondly, we examine the effect of structural breaks on the stability of the relationship between CO_2 emissions per capita and GDP per capita during the period 1962-2014. To achieve these objectives, ARDL approach of cointegration with structural breaks is carried out, followed by stability tests of CUSUM and CUSUM square. The main results of this study are as follows:

1) The ARDL bounds test indicated the existence of a cointegration relationship between CO_2 emissions per capita and GDP per capita.
2) The long term estimation results show that the coefficients of GDP per capita and GDP squared per capita affect CO_2 emissions per capita significantly with positive and negative signs respectively. This implies the validity of the EKC hypothesis for Algeria during the period 1962-2014.
3) In the long term, CO_2 emissions are more income elastic, since a 1% increase in GDP per capita leads to a 65% increase in CO_2 emissions per capita.
4) The turning point of GDP per capita is approximately equal to $4125.58 (constant 2010 $). Algeria attained this per capita income level in 2005. According to the logic of the EKC, Algeria moved to a service-intensive economy.
5) In the case of a possible short-term shock, the variables adjust towards their equilibrium levels at a speed of 35% each year, requiring approximately three years to return to equilibrium.
6) Short-term results show the absence of the EKC, as it is a long-term phenomenon.
7) The inclusion of structural changes in modelling the relationship between the environment and growth leads to model stability.

These results imply that economic growth in Algeria can be a solution to environmental pollution, but only if it is accompanied by a drop in emissions through the promotion of clean energy. The introduction of clean energy into the production process can not only support and promote growth and development, but also contribute to the reduction of carbon emissions. Other determinants of carbon dioxide emissions, such as the use of biofuels for energy production, advanced technologies to control CO_2 emissions, environmental awareness, urbanization, foreign direct investment, and employment, could be explored in future research.

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