Foreign Direct Investment and Environmental Degradation in Algeria: An ARDL Approach

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DOI: 10.24818/mer/2025.02-05

ABSTRACT
This study investigates the relationship between foreign direct investment (FDI) and environmental degradation in Algeria from 1990 to 2022. Employing an Autoregressive Distributed Lag (ARDL) approach, the research analyses the short- and long-run impacts of FDI, GDP growth, fossil fuel consumption, and manufacturing emissions on CO_2 emissions per capita. The ARDL model reveals a weak positive short-run relationship between FDI and CO_2 emissions, consistent with the pollution haven hypothesis. However, in the long run, no significant relationship exists. GDP growth significantly impacts CO_2 emissions, aligning with the Environmental Kuznets Curve. Unexpectedly, manufacturing emissions show an inverse relationship with overall pollution, possibly due to Algeria's less industrialised, rent-based economy. The study concludes that Algeria needs stronger institutional frameworks and sustainable policies to mitigate FDI's environmental impact.

KEYWORDS: *foreign direct investment, environmental degradation, Algeria, ARDL, CO_2 emissions, Pollution Haven Hypothesis.*

JEL CLASSIFICATION: *F21, Q56, Q55, C22, F18.*

1. INTRODUCTION

The interplay between economic policy objectives and environmental considerations has become increasingly complex and poses a significant challenge for decision-makers. This is especially true in the context of attracting foreign direct investment (FDI), which is influenced by various determinants that developing countries strive to provide. However, the question arises: does the effort to attract FDI become constrained by its potential environmental repercussions? This intricate relationship is often analysed through two competing theories. The Pollution Haven Hypothesis (PHH) suggests that countries with weaker environmental standards tend to become destinations for industries with high pollution outputs, thereby exacerbating environmental degradation (Mukiyen Avcı, 2023). Conversely, the pollution halo hypothesis posits that foreign direct investment (FDI) can serve as a conduit for technological and managerial knowledge transfer, potentially facilitating environmental performance improvements in recipient economies through advanced, more sustainable industrial practices (Teng et al., 2021). Empirical research on these hypotheses has produced mixed and inconclusive results in different contexts, prompting scholars to explore more nuanced relationships. Country-specific factors such as institutional quality, economic complexity, and levels of development have been identified as key moderators of the FDI-environment link (Kalmaz & Adebayo, 2024). Furthermore, the use of comprehensive environmental measures, such as the ecological footprint and trade-adjusted carbon emissions, has provided deeper insights into this relationship (Arogundade et al., 2022) . For example, Tsoy and Heshmati (2023) conducted a comprehensive panel study across 100 countries from 2000-2020,

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empirically testing the pollution haven and pollution halo hypotheses. Their findings revealed no statistically significant relationship between foreign direct investment (FDI) and the Environmental Performance Index (EPI), effectively challenging existing theoretical assumptions about FDI's environmental impact mechanisms. In contrast, Viglioni et al. (2024) found that while FDI initially increases emissions in G20 countries, its interaction with institutional quality reduces environmental degradation, suggesting that institutional strength can moderate FDI's environmental impact. Similarly, Mukiyen Avcı (2023) time series analysis of Turkey (1984-2018) found evidence supporting both the pollution haven and pollution halo hypotheses, with institutional quality acting as a mitigating factor. Recent studies have also emphasised the non-linear dynamics of the FDI-environment relationship. Kalmaz and Adebayo (2024) showed that FDI inflows, when combined with higher economic complexity, reduce carbon emissions in BRICS nations, revealing a more intricate interplay between these variables than previously understood. Regional studies, such as those by Azam and Raza (2022), further highlight the importance of context. While FDI was found to increase trade-adjusted carbon emissions in Asia and Africa, its impact was non-significant in Latin America, and a threshold effect was detected in the ecological footprint of African countries.

Despite significant advancements, a clear gap persists in the existing literature regarding Algeria, a resource-rich developing nation. Its growing emphasis on attracting foreign direct investment (FDI) may overlook the strategic foresight required to account for environmental dynamics. This study seeks to explore the interplay between FDI and environmental sustainability by employing advanced econometric techniques, notably the autoregressive distributed lag (ARDL) model. This approach aims to provide robust insights into both the short- and long-term impacts of FDI on environmental quality.

2. LITERATURE REVIEW

Different past researches (Table 1) have focused on foreign direct investment (FDI) and its relationship with environmental destruction, which was measured in most cases using carbon dioxide emissions. The results in any of these cases were inconclusive, that is, some literature gave credence to the pollution haven hypothesis (PHH), while others lent support to the pollution halo effect (PHE) (Luo et al., 2022). The study focused on the effects of foreign direct investment on economic growth and carbon emissions of China, India, and Singapore within the time frame of 1980 to 2020, panel cointegration approach together with various estimation techniques was utilised in the analysis of their data. The findings indicated that FDI expansion positively impacted economic growth and at the same time provided evidence for the Pollution Haven Hypothesis (PHH) (Dhrifi et al., 2020)**.** The research assessed the causal links between foreign direct investment, carbon dioxide emissions, and poverty in 98 developing countries from the year 1995 to 2017, incorporating simultaneous equations models to deal with endogeneity. In these results, there was bi-directional causality between FDI and CO_2 emissions and between CO_2 emissions and poverty. These were indeed revealing and emphasised interlinkages between the three variables (Vo & Ho, 2021)**.** The research looked at the intricate relationships between foreign direct investment and economic growth and environmental degradation in Vietnam since the economic reforms of 1986, employing advanced econometric techniques, including ARDL and threshold regression. The findings critically revealed that FDI exerts a long-term negative impact on environmental quality, with this deterioration becoming particularly pronounced at higher levels of economic growth, thus highlighting the complex trade-offs between economic development and environmental sustainability. Nadeem et al. (2020) investigated the existence of the PHH in Pakistan using ARDL bounds testing on yearly data from (1971-2014). They found a positive long-term relationship between FDI inflow and various pollutants in some models, but overall, no conclusive evidence of the PHH for Pakistan.

Opoku and Boachie (2020) examined the environmental impact of FDI and industrialisation in 36 African countries from 1980 to 2014 using the PMG. They found that the effect of FDI on the environment was largely significant, while industrialisation's effect was generally insignificant. Pavlović et al. (2021) studied the impact of FDI and economic growth on environmental degradation in Balkan countries from 1998 to 2019. They confirmed the PHH in several countries, including Serbia, Albania, Croatia, Romania, and Bulgaria, while rejecting the Environmental Kuznets Curve (EKC) hypothesis. Bharadwaj (2020) analysed the relationship among FDI inflows, economic growth, and carbon emissions in India using Dynamic Ordinary Least Squares (DOLS). The study found a significant non-linear positive relationship between both FDI inflows and GDP per capita with CO_2 emissions, supporting the existence of the PHH. Warsame (2022) explored the impact of FDI, renewable energy, and other factors on CO_2 emissions in Somalia between 1990 and 2019 using an ARDL model. While renewable energy was found to contribute negatively to environmental degradation, the study found no evidence of a causal relationship between FDI and environmental degradation. Odugbesan and Adebayo (2020) investigated the symmetric and asymmetric effects of financial development, FDI, energy consumption, and GDP on CO_2 emissions in Nigeria from 1981 to 2016 using linear and non-linear ARDL techniques. They found that FDI had both linear and asymmetric relationships with CO_2 emissions in the short and long run. Awan et al. (2022) analysed the impact of renewable energy, internet use, and FDI on CO_2 emissions in 10 emerging countries from 1996 to 2015 using the Method of Moments Quantile Regression. They found that FDI had a significant positive effect on emissions at lower quantiles, but became insignificant at higher quantiles. Chiriluș and Costea (2023) investigated the links between carbon dioxide (CO_2) emissions, trade liberalisation, economic expansion, and foreign direct investment (FDI) in the Romanian economy. Their empirical analysis revealed a meaningful long-run association among these variables, with gross domestic product (GDP) growth exhibiting a stronger influence on FDI inflows compared to the impact of CO_2 emissions. Tancho et al. (2020) investigated the asymmetric impacts of macroeconomic variables on environmental degradation in Thailand using a Non-linear Autoregressive Distributed Lag (NARDL) approach. Their study, covering the period 1990-2018, revealed non-linear relationships between environmental degradation and factors such as FDI, trade openness, industrialisation, economic growth, and globalisation. The findings suggest that positive and negative shocks in these macroeconomic variables have differing effects on environmental degradation. Eweade et al. (2024) investigated the asymmetric impacts of fossil fuel consumption, foreign direct investment (FDI), and globalisation on Mexico's ecological footprint over the period 1975 to 2020. Using both ARDL and NARDL methods, together with wavelet coherence analysis, they found that economic growth and fossil fuel consumption led to ecological degradation. Interestingly, their ARDL results showed that FDI improved environmental conditions, while the NARDL approach indicated that positive shocks to FDI degraded the environment. Samreen et al. (2021) focused on Pakistan, using an ARDL bound test to analyse the relationship between FDI, trade openness, urbanisation, economic development, and CO_2 emissions from 1970 to 2018. Their results supported the Pollution Haven Hypothesis (PHH), showing that increases in FDI led to higher CO_2 emissions and environmental degradation in both the short and long run. In contrast, Gyimah et al. (2023) examined the role of Chinese FDI in Ghana's carbon emissions from 2000 to 2020 using the generalised method of moments. Their findings supported the pollution halo hypothesis, indicating that Chinese FDI mitigated carbon emissions in Ghana. However, they also found that exports from China worsened environmental degradation. Njumwa et al. (2022) studied the nexus between macroeconomic variables and carbon emissions in Kenya from 1983 to 2019, employing the Environmental Kuznets Curve (EKC) hypothesis and the ARDL model. Their results showed a positive long-run relationship between CO_2 emissions and FDI, while trade openness had a negative relationship with emissions in the long run.

Table 1. Review of existing studies

Author(s)	Study Location	Methodology	Relationship Direction
Luo et al. (2022)	China, India, Singapore	Panel cointegration, AMG, CCEMG, MG estimators	Positive (FDI to CO_2)
Dhrifi et al. (2020)	98 developing countries	Simultaneous-equations models	Bi-directional (FDI and CO_2)
Vo and Ho (2021)	Vietnam	ARDL, Threshold regression	Positive (FDI to environmental degradation)
Nadeem et al. (2020)	Pakistan	ARDL bounds test	Mixed (some positive, inconclusive overall)
Opoku and Boachie (2020)	36 African countries	Pooled Mean Group estimation	Significant positive (FDI to environment)
Pavlović et al. (2021)	Balkan countries	Pearson correlation, Polynomial regression	Positive (FDI to environmental degradation)
Bharadwaj (2020)	India	Dynamic Ordinary Least Squares	Non-linear positive (FDI to CO_2)
Warsame (2022)	Somalia	ARDL	No causal relationship found
Odugbesan and Adebayo (2020)	Nigeria	Linear and Non-linear ARDL	Positive (both symmetric and asymmetric)
Awan et al. (2022)	10 emerging countries	Method of Moments Quantile Regression	Positive at lower quantiles, insignificant at higher
Chiriluș and Costea (2023)	Romania	Not clearly specified	Significant relationship (FDI and CO_2)
Tancho et al. (2020)	Thailand	NARDL	Non-linear/asymmetric relationship
Eweade et al. (2024)	Mexico	ARDL, NARDL, Wavelet coherence	Positive (FDI to environmental degradation)
Samreen et al. (2021)	Pakistan	ARDL bound test	Positive (FDI to CO_2)
Gyimah et al. (2023)	Ghana	Generalised method of moments	Negative (Chinese FDI to CO_2)
Njumwa et al. (2022)	Kenya	ARDL	Positive (FDI to CO_2)

Source: prepared by the researcher

3. DATA AND MODEL

For this study, we will employ variables including environmental pollution (CO_2 emissions per capita) as the dependent variable and Foreign Direct Investment, GDP per capita, Fossil fuel energy consumption, CO_2 emissions from manufacturing industries, and construction as independent variables. It is worth noting that these data are sourced from the World Bank's database; the metric unit and a detailed description of these variables were explicitly specified in Table 2. The scope of this investigation spans from 1990 to 2022.

Before studying stationarity and estimating the relationship between the dependent variable and the explanatory variables, it is necessary to perform a statistical evaluation of the study variables. Table 2 presents descriptive statistics for five variables (Lnco2cap, Lninv, Lngdp, Lnfec, and Lncomc). The mean and median values of most of the variables are relatively close, indicating fairly similar distributions, albeit with a possible slight skew.

Table 2. Description of the variables used in the study

Abbreviations	Variables	Unit	Data Source
Lnco2cap	CO_2 emissions per capita	Metric tons	World Bank (2023)
lninv	Foreign Direct Investment, net inflows	(Balance of Payments, current US dollars)	World Bank (2023)
lngdp	GDP per capita	Constant 2010 US$	World Bank (2023)
lnfec	Fossil fuel energy consumption	(% of total)	World Bank (2023)

Abbreviations	Variables	Unit	Data Source
Lncomc	CO_2 emissions from manufacturing industries and construction	(% of total fuel combustion)	World Bank (2023)

Note: Given that some model variables are expressed as percentages, we first converted them to decimal form before applying a logarithmic transformation. This approach enhances the precision of the analysis by normalising the data, mitigating skewness.

Source: prepared by the researcher

For example, the mean per capita CO_2 emissions (Lnco2cap) of 1.10977 is slightly higher than the median of 1.09365, indicating a right-skewed distribution. For investments (Lninv), the mean of 7.695 is lower than the median of 9.0273, indicating a possible leftward skew, while GDP (Lngdp) shows a similar pattern, with a mean of 8.177 slightly lower than the median of 8.238, indicating possible outliers affecting the mean. The standard deviation of CO_2 emissions (Lnco2cap) is 0.168098, which is relatively low compared to the mean, indicating that the data points are close to the mean, while investment (Lninv) shows a high standard deviation of 3.482033, indicating a larger variance of the same conclusion relative to the variables (lngdp, lnfec). Skewness: Most of the variables show some degree of skewness. Lnco2cap shows a slight positive skewness (0.341293), indicating a right tail, while Lninv shows a strong negative skewness (-3.52169), indicating a long-left tail. GDP (Lngdp) shows a slight negative skew (-0.34406), energy consumption (Lnfec) shows a negative skew (-1.474), while communications (Lncomc) show a positive skew (1.173). Kurtosis: All variables have positive kurtosis (> 0), with lninv showing the highest kurtosis (16.307), indicating a positive kurtosis distribution (sharp top and fat tails). This contrasts with the slightly naive distributions of the other variables. The Jarque-Bera (J-B) test statistics and associated probabilities indicate that most variables follow a normal distribution. However, the Lncomc variable stands out with a J-B statistic of 7.85 and a low probability, indicating that it deviates from a normal distribution. Scale differences: The variables are on vastly different scales, as investment (Lninv) is in billions, while other variables, such as CO_2 emissions per capita, are on a much smaller scale.

Table 3. Descriptive statistics

Variable	Mean	Median	Std.dev	Skewness	Kurtosis	J-B	S.S. Dev.	Obsv
Lnco2cap	1.10977	1.09365	0.16809	0.34129	1.5972	3.346	0.904219	33
lninv	7.695	9.0273	3.48203	-3.5216	16.307	311.70	387.9857	33
lngdp	8.177	8.238	0.14201	-0.3440	1.5060	3.719	0.64534	33
lnfec	-2.409	-2.309	0.296	-1.474	4.111	13.656	2.809	33
lncomc	-0.0006	-0.0012	0.002	1.173	3.4506	7.8502	0.0001	33

*, **, and *** represent 1%, 5%, and 10% levels of significance, respectively.

Source: author estimation

To analyse the relationship between FDI and CO_2 emissions per capita in Algeria, we developed our model based on a thorough review of existing literature and empirical evidence. From this theoretical foundation, we propose the following econometric formulation:

$$co2cap = f(inv, gdp, fec, comc) \tag{1}$$

The implemented model may be articulated in logarithmic-linear formulations as delineated below:

$$\text{Lnco2cap}_t = \beta_0 + \beta_1 \text{lninv}_t + \beta_2 \text{lngdp}_t + \beta_3 \text{lnfec}_t + \beta_4 lncomc_t + \varepsilon_t \quad (2)$$

Lnco2cap_t , lninv_t , lngdp_t, $\text{lnfec}_t and\ lncomc_t$ are the logarithmic forms of co2cap_t , $\text{inv}_{t\,,}$ gdp_t,
$\text{fec}_t and\ comc_t$ respectively, whileε_t is the error term and β_0 is a constant.

4. METHODOLOGY

The ARDL approach was designed to bypass the need for certain prerequisites and directly identify the integration order of the variables. In testing the hypothesis of both long-run and short-run coefficients of the input variables, ARDL demonstrated robustness, regardless of whether the variables are integrated at mixed levels, such as I(0) and I(1). Model selection in the ARDL framework is guided by the Akaike Information Criterion (AIC). The ARDL model is expressed in the form of the Unrestricted Error Correction Model (UECM), we will start from the ARDL equation (2), where the variables of our study will be expressed in the model as follows:

$$\Delta(\text{lnco}_2\,\text{cap}_t) = \alpha_0 + \sum_{i=1}^{q_1} \psi_{1i}\Delta(\text{lnco}_2\,\text{cap}_{t-i}) + \sum_{i=0}^{q_2} \psi_{2i}\Delta(lninv_{t-i}) + \sum_{i=0}^{q_3} \psi_{3i}\Delta(\text{lngdp}_{t-i})$$
$$+ \sum_{i=0}^{q_4} \psi_{4i}\Delta(\text{ lnfec }_{t-i}) + \sum_{i=0}^{q_5} \psi_{5i}\Delta(\text{lncomc}_{t-i}) + \pi_1(\text{lnco}_2\,\text{cap}_{t-i}) + \pi_2(\text{lninv}_{t-i}) + \pi_3(\text{lngdp}_{t-i})$$
$$+ \pi_4(\text{ lnfec }_{t-i}) + \pi_5(\text{lncomc}_{t-i}) + \varepsilon_t \quad (3)$$

The constant term, α_0, represents the intercept of the model. The symbol Δ denotes the first difference of the variables, capturing short-term changes. The terms q_1, q_2, q_3, q_4, and q_5 refer to the distributed lag periods, which account for the delayed effects of the independent variables. The coefficients $\psi_{1i}, \psi_{2i}, \psi_{3i}, \psi_{4i}$ and ψ_{5i} represent the short-run dynamic impacts of the lagged changes in the independent variables on the dependent variable. On the other hand, $\pi_1, \pi_2, \pi_3, \pi_4$, and π_5 capture the long-run equilibrium relationship between the dependent and independent variables. In this case, the dependent variable is the logarithm of CO_2 emissions per capita $(\text{Inco2cap})_t$, while the independent variables include the logarithms of Foreign Direct Investment (Ininv), GDP per capita (Ingdp), Fossil fuel energy consumption (Infec), and CO_2 emissions from manufacturing industries and construction (Incomc). Lastly, ε_t represents the error term of the model.

In the classic ARDL method, "F-Bounds" and "t-Bounds" boundary tests are used to examine cointegration. The F-Bounds test considers the lagged values of all dependent and independent variables in the model. The hypotheses of the F-Bounds test are as follows:

$$H_0: \pi_1 = \pi_2 = \pi_3 = \pi_4 = \pi_5$$

Against the alternative hypothesis of the existence of co integrating relationship between the variables,

$$H_1: \pi_1 \neq \pi_2 \neq \pi_3 \neq \pi_4 \neq \pi_5$$

The F-Bounds test statistics are compared with the critical values for the lower and upper bounds calculated by Narayan (2005). If the computed F-Bounds statistic exceeds the upper bound critical value specified for I (1), the null hypothesis (H_0) of no cointegration is rejected, indicating the presence of cointegration. Conversely, if the F-Bounds statistic falls between the lower and upper bound critical values, The null hypothesis of no cointegration remains inconclusive, representing a region of uncertainty. If the error correction term is negative and statistically significant (with a p-value less than 0.05), it will suggest the existence of a long-term relationship among the predicted variables. However, if the F-Bounds value is below the lower bound critical value, it indicates the absence of cointegration.

The short-term dynamics is expressed in an error correction model, which captures both short-term changes and the adjustment towards the long-term equilibrium. The short-term model in the ECM form is:

$$\Delta Lnco2cap_t = \alpha_0 + \sum_{i=1}^{q_1} \beta_0 \Delta\left(\mathrm{lnco_2\ cap}_{t-i}\right) + \sum_{i=0}^{q_2} \beta_1 \Delta \mathrm{lninv}_{t-i} + \sum_{i=0}^{q_3} \beta_2 \Delta \mathrm{lngdp}_{t-i} + \sum_{i=0}^{q_4} \beta_3 \Delta \mathrm{lnfec}$$
$$+ \sum_{i=0}^{q_5} \beta_3 \Delta \mathrm{lncomc} + \phi EC_{t-1} + \varepsilon_t$$

Where ϕEC_{t-1} is the error correction term that measures how quickly the dependent variable adjusts towards the long-term equilibrium. EC_{t-1} is the lagged residuals from the long-term equation, ε_t is the short-term error term.

5. EMPIRICAL RESULTS

5.1. Unit Root test

The main objective of unit root testing is that time series often produce spurious results because of the presence of a unit root in these series. This leads to spurious relationships among variables. Therefore, the purpose of unit root testing is to examine the properties of time series for each variable under study and to determine the order of integration of each variable individually, using the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The results were as follows:

Table 4. Unit root test

	Level I (0)				**First difference I (1)**			
test	**ADF**		**PP**		**ADF**			**PP**
variables	**t-Stat.**	**Prob.**	**t-Stat.**	**Prob.**	**t-Stat.**	**Prob.**	**t-Stat.**	**Prob.**
Lnco2cap	0.161840^{N}	0.7262	0.6408^{N}	0.8495	-3.1359$^{\mathbf{N}}$	0.0028*	-3.1725$^{\mathbf{N}}$	0.0025
lninv	-5.0059C	0.0003*	-5.0043^{C}	0.0003*	-	-	-	-
lngdp	1.413384^{N}	0.9575	1.1060^{N}	0.9266	-3.575668$^{\mathbf{N}}$	0.0008*	-3.5997$^{\mathbf{N}}$	0.0008
lnfec	-0.128019^{T}	0.9920	1.2013^{T}	0.9999	-6.726904$^{\mathbf{T}}$	0.0000*	-9.988 $^{\mathbf{T}}$	0.0000
lncomc	3.11901^{C}	1.0000	3.3749^{C}	1.0000	-5.038240	0.0016	-5.1174	0.0013

*, **, *** indicate statistical significance at the 1%, 5% and 10% level, with an intercept and automatic selection of Schwarz Information Criterion (SIC. ADF, PP are the empirical statistics of the Augmented Dickey–Fuller, Phillips–Perron, **N:** Model with no trend not intercept. **T+C**: Model with trend and intercept. **C:** Model with intercept

Source: prepared by the researcher using EViews 13

Based on the table above (table 4), we conducted Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to examine the presence of unit roots at the 5% significance level for all variables. The results indicated that the foreign direct investment variable is stationary at

levels, as demonstrated by the probability value of 0.0003 for the lninv series in both ADF and PP tests, confirming its stationarity at levels and suggesting that it is integrated of order zero, I(0).
On the contrary, the remaining variables (Lnco2cap, lngdp, lnfec, and lncomc) were not stationary at levels. After applying the first difference to each time series separately, we observed that all critical values (in absolute terms) for these variables in both the ADF and the PP tests were lower than the calculated statistical values. This is further evidenced by the probability values presented in Table 4, indicating that these time series are stationary at the first difference, I(1).

5.2. Testing for Long-Run Equilibrium Relationships in the Model

The analysis proceeds using the Bounds test approach. The results of this test are presented in Table 5 below:

Table 5. Bounds Test Results

Long-term F bounds test			
	F-statistics = **14.1505**		
Signif.	lower bound I(0)	upper bound I(1)	Conclusion
10%	2.46	3.46	
5%	2.947	4.088	
1%	4.093	5.532	

Source: prepared by the researcher using EViews 13

The results presented in Table 5 indicate that at the 5% significance level, the computed F-statistic= 14.1505 exceeds the upper bound critical value I(1) in the presence of four explanatory variables (k=4) and a constant term. Consequently, we reject the null hypothesis H_0 and accept the alternative hypothesis H_1, implying the existence of a long-run equilibrium relationship.

5.3 Results of the ARDL Model

Given that the results confirm the presence of cointegration, it is necessary to estimate both the short-term relationship using the Error Correction Model (ECM) and the long-term relationship based on the ARDL (Autoregressive Distributed Lag) approach as follows Table 6.

Table 6. ARDL unconditional error correction regression

ARDL model short-run levels equation estimation				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob**
D(lnco2cap(-1))	0.898357	0.121233	7.410171	0.0007
D(lnco2cap(-2))	0.398140	0.150292	2.649100	0.0455
D(lninv)	-9.56E-05	0.000865	-0.110503	0.9163
D(lninv(-1))	0.007663	0.001206	6.352698	0.0014
D(lninv (-2))	0.005125	0.001132	4.525748	0.0062
D(lninv (-3))	0.002095	0.000764	2.743095	0.0406
D(lngdp)	0.467703	0.151090	3.095523	0.0270
D(lngdp (-1))	-0.710429	0.164556	-4.317236	0.0076
D(lngdp (-2))	-0.126248	0.209684	-0.602090	0.5734
D(lngdp(-3))	1.025621	0.249995	4.102567	0.0093
D(lnfec)	12.47545	8.612057	1.448603	0.2071

ARDL model short-run levels equation estimation				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob**
D(lnfec (-1))	-12.10463	6.832294	-1.771679	0.1367
D(lnfec (-2))	-13.82014	8.455817	-1.634395	0.1631
D(lnfec (-3))	18.37242	7.274990	2.525422	0.0528
D(lncomc)	-0.246229	0.072559	-3.393500	0.0194
D(lncomc (-1))	-0.426313	0.121277	-3.515199	0.0170
D(lncomc (-2))	-0.360998	0.090120	-4.005737	0.0103
D(lncomc (-3))	-0.609422	0.116089	-5.249618	0.0033
CointEq(-1)*	-0.879616	0.124638	-7.057377	0.0009
R^2 = 0.962227 ADJ R^2 = 0.918643 S.E. of regression=0.011420				
ARDL model long-run levels equation estimation				
LNINV	-0.009853	0.005094	-1.934311	0.1109
LNGDP	0.828331	0.166738	4.967854	0.0042
LNFEC	31.32708	43.05121	0.727670	0.4994
LNCOMC	0.325486	0.277686	1.172134	0.2939
C	-4.842090	1.885786	-2.567677	0.0502
Note: *, **, *** indicate statistical significance at the 1%, 5% and 10% level, respectively.				

Source: prepared by the researcher using EViews 13

According to the results in the Table 6, we observe that the coefficient of CointEq (-1) has a negative sign (-) and is statistically significant based on the p-value statistic (Prob= 0.0009 < 5%). This confirms the cointegration results according to the ARDL approach. The estimated value of the error correction term CointEq(-1) is -0.87961, indicating that 87.96% of the disequilibrium in the CO_2 emissions variable from the previous period (t-1) is corrected in the current period (t).

The error correction model equation reveals that the foreign direct investment variable (lninv) with lags from one to three periods is statistically significant and shows a weak positive relationship with CO_2 emissions. This supports the pollution haven hypothesis (PHH) consistent with findings from previous studies such as Luo et al. (2022), Dhrifi et al. (2020), and Vo and Ho (2021). Specifically, a 1% increase in foreign direct investment inflows leads to increases in per CO_2 emissions of 0.76%, 0.51%, and 0.2% at (t-1), (t-2), and(t-3) period lags, respectively.

From the ECM equation, we observe a significant positive relationship between both the current GDP (lngdp) and three-period lagged GDP (lngdp(-3)) with CO_2 emissions. This supports the Environmental Kuznets Curve (EKC) hypothesis, which explores the relationship between economic growth and environmental degradation. The hypothesis suggests that initially, as per capita GDP rises in a country, environmental degradation increases due to industrialisation and economic growth. The results show that a 1% increase in current GDP (lngdp) and three-period lagged GDP (lngdp(-3)) leads to increases in CO_2 emissions of 0.46% and 1.02%, respectively. Notably, we also observe an unexpected significant negative relationship for the $\text{lngdp}(-2)$.

There is an insignificant relationship between both current and lagged (one and two periods) fossil fuel energy consumption and CO_2 emissions. This may be attributed to a delayed response in the dependent variable. However, a significant positive relationship appears in the third period, indicating that a one-unit increase in fossil fuel energy consumption leads to a 18.13% increase in environmental pollution. An inverse relationship emerged between CO_2 emissions from manufacturing and construction industries and overall environmental pollution, an unexpected result. This may be explained by the limited contribution of emissions from these sectors to pollution, given that Algeria's economy is primarily rent-based and does not rely heavily on manufacturing and construction industries.

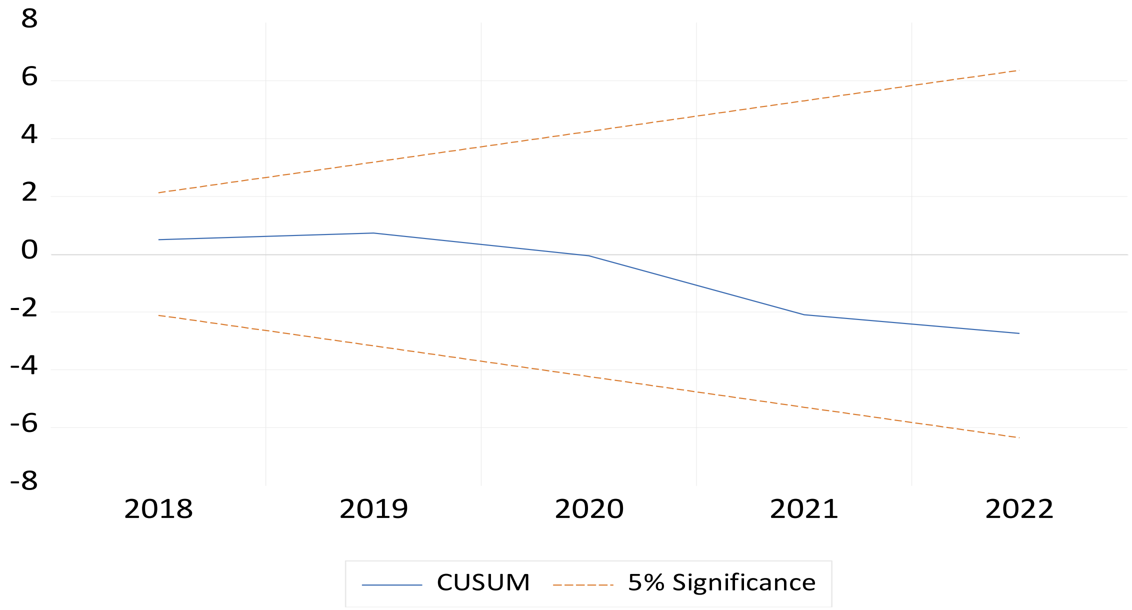
As shown in the Table 6, the estimated long-term relationship reveals no significant relationship between foreign direct investment (FDI) and per capita CO_2 emissions. This finding aligns with the error correction model results, which indicated a weak link between FDI and environmental pollution. It also highlights that environmental pollution rates in Algeria are more closely associated with other, more influential factors than FDI inflows.

Table 7. Results of the different diagnostic tests of the estimated model

Test Hypotheses	Tests	Values	Prob.
Serial correlation LM(2)	Breusch-Godfrey	F stastique =1.1744 Obs*R-squared=12.735	0.4200
Heteroscedasticity	Breusch-Pagan-Godfrey	F stastique=0.440294 Obs*R-squared=19.4143	0.9188
Heteroscedasticity	Arch-Test	F stastique=0.231151 Obs*R-squared=0.2467	0.6347
Normality	Jarque-Bera	JB=8.639949	0.01330**
Specification	Ramsey	F stastique= 5.3950	0.0809***
Note: *, **, *** indicate statistical significance at the 1%, 5% and 10% level, respectively.			

Source: Prepared by the researcher using Eviews 13

The Breusch-Godfrey LM test for serial correlation indicates that the p-value is not statistically significant (Prob-value = 0.42), suggesting that the model is free from serial correlation issues. Regarding the normality of the residuals, the Jarque-Bera (JB) test, as shown in the same table 7, supports the null hypothesis that the residuals are normally distributed. Specifically, the p-value of the JB test is 0.01, which exceeds the 1% significance level, leading us to accept that the residuals follow a normal distribution. Additionally, the ARCH test is used to evaluate the homoscedasticity (or constant variance) of the residuals. Based on the Obs*R-squared value, with a corresponding p-value of 0.6347 (greater than the 5% threshold), we accept the null hypothesis of homoscedasticity. This conclusion is further supported by the Breusch-Pagan-Godfrey test, which yields a p-value of 0.9188, reinforcing the absence of heteroscedasticity in the model. Finally, the Ramsey RESET test, with a p-value of 0.0809, also exceeds the 5% significance level, indicating that the functional form of the model is correctly specified. Therefore, the model under study is deemed robust in terms of specification and reliability.



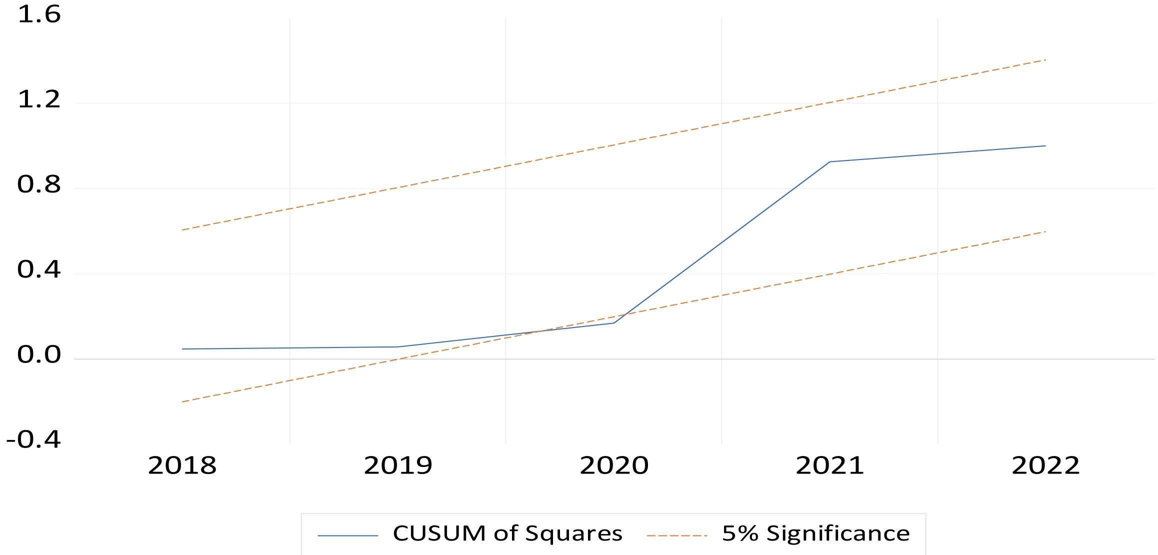


Figure 3. CUSUM and CUSUMSQ stability plots of the ARDL

Source: Prepared by the researcher using Eviews 12

The structural stability of the model is assessed using the CUSUM and CUSUMSQ tests. Figure 1 presents the results of these tests. From the graphical representation, it is evident that the cumulative sum of the residuals (CUSUM) remains within the critical boundaries, indicating that the model is stable at the 5% significance level. Similarly, the CUSUMSQ test, which assesses the cumulative sum of squared residuals, also suggests stability in the model. This indicates consistency between the long-term and short-term results, confirming the model's overall stability and robustness.

6. CONCLUSIONS

Employing an autoregressive distributed lag (ARDL) model, this study examines the multidimensional interplay of foreign direct investment (FDI) and environmental degradation in Algeria's economy while analysing its short and long term dynamic changes. The findings were framed within the context of economic and environmental development, which identified numerous complexities and new opportunities. In the short term, FDI had a weak positive correlation with CO_2 emissions consistent with the 'pollution haven' theory where FDI is presumed to flow into regions with less rigorous environmental controls. On the other hand, the long-term analysis showed the absence of a significant relationship between carbon emissions per capita and FDI, suggesting that the causative factors of pollution are much more intricate and intertwined with other macroeconomic elements.

With regards to policy recommendation for Algeria's investment, it is necessary to establish stronger institutional barriers and reorganise the investment approach so that economic growth can be matched with environmental protection. This entails shaping stringent environmental laws geared towards promoting green investment and redirecting the economy from being resource-driven to resource-based. Investing in renewable energies and promoting clean technology is a key strategy to mitigate negative environmental impacts.

The research opens important avenues for future studies, suggesting in-depth analyses in areas such as detailed sectoral impacts, links between foreign investment and environmental innovations, and comparative studies with similar economies. This study represents a scholarly contribution to understanding economic and environmental complexities, and offers a critical view of investment policies in developing countries with rentier economies.

In conclusion, the findings emphasise the importance of a holistic and integrated view of development, as economic growth cannot be separated from environmental considerations. The real challenge lies in finding sustainable development paths that strike a balance between the requirements of growth and the preservation of natural resources for future generations.

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