

Determinants of Cleaner Production in the Algerian Economy An Econometric Analysis for the Period 2000–2023

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Abstract:

The aim of this research is to analyze the determinants of cleaner products in the Algerian economy during the period 2000–2023, based on an econometric approach that links cleaner products with several economic and environmental variables such as GDP, clean energy consumption, carbon emissions, spending on research and development. Data was collected from reliable national and international sources, including the National Statistics Office (financial statements) and the World Bank, and analyzed using the Autoregressive Lag Diagram (ARDL) model. The results showed a strong correlation between the shift towards cleaner production and the level of economic growth and energy efficiency, with environmental policies having a positive impact on reducing pollution. The study underscores the importance of supporting cleaner products to promote a cleaner economy in Algeria.

Keywords: Cleaner product, Algerian economy, economic growth, environmental pollution, Autoregressive Lag Delay (ARDL).

JEL Classification Codes : O13 ; O33.

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1. INTRODUCTION

The shift towards cleaner production has become one of the most important global economic trends in recent decades. Achieving sustainable development has become an urgent necessity to address environmental degradation caused by industrial activities and excessive resource consumption. Cleaner products are a fundamental pillar for achieving this balance. Because it aims to improve production efficiency while reducing emissions, waste and energy consumption, thus contributing to environmental protection and supporting the green economy.

In Algeria, the importance of this trend has emerged within the national strategies for energy transition and modernization of the industrial system, but the assessment of the determinants of cleaner products at the macro level is still limited in terms of quantitative analysis and standard study.

Based on this, the research problem can be summarized in the following question:

What are the economic and environmental factors influencing cleaner production in the Algerian economy during the period 2000–2023?

From this problem, the following hypotheses emerge:

- There is a positive relationship between economic growth and cleaner production in Algeria.
- High energy consumption and carbon emissions lead to lower levels of cleaner production.
- Investment in research and development contributes to improved environmental performance and the promotion of cleaner products.

The study of (chung, Fare, & Grosskopf, 1997) “Productivity and undesirable outputs: A directional distance function approach” is among the primary reference studies in analyzing the relationship between productive activity and environmental pollution. The researchers show that the environmental problem associated with the production of goods is mainly due to the nature of the outputs resulting from the production process, which can be divided into desirable

outputs represented in goods and services, and undesirable outputs represented in environmental pollutants such as solids, liquids and carbon dioxide emissions. This approach emphasizes that improving the efficiency of the production process and improving the quality of goods to achieve cleaner production at the same time leads to a reduction in the pollutants associated with the production process. On this theoretical basis, CO₂ intensity can be used as an indicator of the cleanliness of the production process and progress towards a cleaner product.

The study aims to analyze the relationship between cleaner products and a number of economic and environmental variables, and to identify its most important determinants using the time-standard analysis method for Algerian economic data during the study period.

Data from reliable national and international sources such as the National Statistics Office and the World Bank were used, with time regression tools employed to test hypotheses and interpret results.

2. Cleaner Product Indicators and Economic Factors

2.1. Global Cleaner Product Indicators:

Among the economic indicators used by researchers to describe cleaner products, we mention the following:

Emissions and pollution indicators :

- Carbon dioxide emissions per unit of GDP, measured in kg or tonne CO₂/USD of GDP; (Statistics, Metadata for Indicator 9.4.1: CO₂ emissions per unit of GDP, 2025, p. 3)
- Total greenhouse gas emissions, measured in tons of CO₂ equivalent; (Division, Metadata for Indicator 11.6.2: Annual mean levels of fine particulate matter (PM_{2.5}), 2023, p. 4)
- Industrial pollution intensity, measured in tons of pollutants per industrial output value; ((OECD), Do environmental policies affect global value chains? (ENV/WKP(2016)6), 2016, p. 34)
- Air quality, PM_{2.5} concentration, measured in µg/m³. (Statistics, 2023, p. 4)

Energy and resource efficiency indicators: (IEA, 2022) (OECD, 2014)

- Energy intensity, measured in kilograms of oil equivalent per dollar; (Division, 2025, p. 4)
- Resource productivity, measured in dollars per kilogram of resource; (Division, 2025, p. 5)
- Energy efficiency index, measured as a percentage (%); ((IEA), Energy Efficiency Indicators 2022, 2022, p. 4)
- Water use efficiency, measured in dollars per cubic meter (m³). (Division, 2024, p. 3)

Clean Energy and Environmental Innovation Indicators:

- Renewable energy share, measured as % of total energy; (Division, 2024, p. 3)
- Carbon dioxide emissions per kilowatt-hour, measured as kg CO₂/kWh; ((IEA), 2023)
- Green patents, measured as the number of patents; ((WIPO), 2022)
- Environmental research and development expenditure, measured as % of GDP or in US dollars. ((OECD), 2021)

Comprehensive Environmental Performance Indicators:

- Environmental Performance Index (EPI), measured on a scale of 0 to 100; (University, 2022)
- Air Quality Index (AQI), measured in micrograms per cubic meter (µg/m³); ((EPA), 2024)
- Total greenhouse gas emissions, measured in tons of CO₂ equivalent; ((IPCC), 2019)
- Industrial pollution intensity, measured in tons per unit of output. (Bank, World Development Indicators – Industry and Environment, 2023)

Circular economy indicators and resource efficiency: (Measuring Resource Efficiency, 2013)

- Recycling rate, measured in %; (Eurostat, 2023)
- Material Circularity Index, measured on a scale of 0 to 1; (MacArthur, 2015, pp. 20-25)
- Waste density, measured in kg/unit of production; (Bank, 2023)

- Environmental Innovation Index, measured on a scale of 0 to 100. (Cornell University, 2023, pp. 143-150)

2.2. Cleaner Product Indicators for the Algerian Economy:

Among the indicators that can be referred to for measuring cleaner products in Algeria are those that have been measured and are found in official national and international administrative reports such as the National Statistics Office, financial reports, the World Bank and the World Development Index (WDI), and the OWID platform, Our World data from Oxford University.

Indicators include:

- Total greenhouse gas emissions, measured in tons of CO₂ equivalent.
- Adjusted savings: CO₂ damage (in US dollars).
- Adjusted savings: CO₂ damage (% of national income).
- Electricity production from oil, gas, and coal sources, measured as a percentage of total energy;
- Gross Domestic Product (GDP), measured in US dollars, and GDP growth rate, measured as a percentage.
- Manufacturing, value added (% annual growth).
- Foreign Direct Investment (FDI), net (in billions of US dollars).
- Research and Development (R&D) expenditure (% of GDP).
- Alternative energy and nuclear energy (% of total energy).

3. Standard study of cleaner products in Algeria

Based on previous studies, such as (Grzegorz, et al., 2022)“R&D, Human Capital, Renewable Energy and CO₂ Emissions: Evidence from 26 Countries”, which examined the relationship between carbon emissions and the number of researchers engaged in R&D activities, economic development, foreign capital flows, renewable energy, and population growth in 26 countries during the period 1995–2015, we developed in our study an econometric model that allows us to identify certain variables influencing cleaner production in Algeria. Among these potentially influential variables, we selected those for which accurate data are available and that do not present missing-value problems in measurement:

- CO₂E: Carbon density.

- GDP: Gross Domestic Product.
- MFG Gt: Ratio of industrial value added to GDP
- FDI: Foreign Direct Investment (%GDP)
- RD_GDPt: Spending on research and development as a percentage of (%GDP).
- ALT_ENT: The share of renewable and nuclear energy in total energy.

The study includes annual observations in the language of 24 observations between the years 2000 and 2023. We also used carbon intensity as an indicator of the cleaner product, while the other variables are independent variables that represent indicators of the economic and environmental aspect, helping us to determine the impact.

3.1 Time-based analysis of model variables:

Fig.1. Curves of variables as a function of time



Source: Prepared by the researcher using Eviews 12 software

CO2Et carbon density: Figure 1 shows the effects of state intervention with pollution control mechanisms such as aid funds and established taxes, but pollution continues to increase throughout the study period. We note a slight decrease in carbon dioxide emissions in 2009 due to the global recession and economic crisis. In 2015, Algeria witnessed a decline in economic growth. As for 2020, there is a double impact: the coronavirus pandemic and the decreasing demand for oil.

Gross Domestic Product (GDP): Figure 1 reflects the country's economic performance and its susceptibility to internal and external factors, which can be divided into two phases.

The first decade of the millennium (2000-2009): Positive growth rates peaked in 2003. Subsequently, the Algerian economy faltered due to the 2008 global financial crisis, leading to a slowdown in growth over the last two years.

The second decade of the millennium (2010-2022): Unstable economic growth. Due to the COVID-19 pandemic in 2020, the decline in oil prices, and the contraction of the global economy.

Ratio of Industrial Value Added to MFG (Gross Domestic Product): Figure 1 shows changes over recent years, reflecting a range of economic factors and industrial policies in Algeria during the period 2010–2020, the industrial sector began a gradual recovery as a result of economic recovery programs and government support for industrial investment, with growth rates ranging between 5.7% and 7%. In 2023, industrial value added reached approximately 1.467 billion dinars, compared to a total GDP of approximately 36.1035 billion dinars.

Foreign Direct Investment (FDI) as a percentage of GDP (FDIt): Based on the data for this variable in Figure 1, we observe fluctuations in Algeria's reception of foreign investment. This is due to several factors, including:

- **Bureaucracy and weak administrative procedures:** Administrative bureaucracy and the difficulty of establishing projects are among the most important reasons that hinder attracting foreign investors, as procedures take a long time, require complex approvals, and are

sometimes subject to duplication and overlap between institutions. (جبار، 2022، صفحة 144)

- Instability of investment legislation and laws: Frequent changes in investment laws (such as the famous 51/49 rule and its partial reversal) weaken confidence in the investment environment and make investors hesitant to inject large capital in the long term. (زاهي و براهمي، 2022، صفحة 34).
- Poor management and difficulty in obtaining industrial real estate: Many foreign projects suffer from problems related to the difficulty of obtaining suitable industrial land and weak supporting infrastructure. (جبار، 2022، صفحة 287)
- Difficulty in obtaining financing and lack of transfer guarantees and property protection: this makes some investments unable to operate efficiently and increases investment risks.

Research and Development Spending (% of GDP) RD GDPt: The series shown in Figure 1 can be divided into three phases. Phase 1 (2000-2008): An increase of no more than 0.2% in the sector's budget due to the enactment of a regulatory law for scientific research. Phase 2 (2008-2012): During this phase, the General Directorate for Scientific Research and Technological Development was established, through which a national strategy for scientific research was developed, and the budget allocation increased by 0.3%.

The share of renewable and nuclear energy in total energy (ALT_ENT): The evolution of the series shows that it is non-linear and fluctuating, as illustrated in Figure 1. This is due to Algeria's lack of a stable energy policy. The primary energy source in Algeria is gas. Regarding the stages of renewable energy production, the first experiment was in 2005 with solar energy projects, followed by an expansion program for renewable energy in 2011. Then funding for these projects decreased due to the global crisis in 2014, followed by an improvement and recovery from the crisis in 2017, and finally stability that began in 2020.

3.2 Standard Study of the Model:

3.2.1 Correlation Testing Between the Independent Variables of the Model:

Table 1. Linear Correlation Table Between Independent Variables.

Correlation	ALT EN	FDI	GDP	MFG G	RD GDP
ALT_EN	1.000000				
FDI	-0.104582	1.000000			
GDP	0.388964	-0.429071	1.000000		
MFG_G	-0.373577	-0.247216	0.308995	1.000000	
RD_GDP	0.481497	-0.264870	0.292340	0.032382	1.000000

Source: Prepared by the researcher based on Eviews 12 outputs

The table shows no linear correlation problem; most relationships between the independent variables are moderate or weak. Therefore, the probable model will be statistically stable in terms of correlations.

3.2.2 Testing the stability of model variables:

The statistical hypotheses for the test are H_0 , the null hypothesis "The variable is unstable and contains a unit root," and H_1 , the alternative hypothesis "The variable is stable and does not contain unit roots."

Table 2.Study of stability at the first and second levels of the study variables.

		CO2E	ALT EN	FDI	GDP	MFG G	RDGDP
Level	T-stat	-2.06	-3.12	-0.67	-2.17	-4.66	-2.97
	T-critic	-2.99	-2.10	-2.10	-2.10	-3.63	-2.10
Level (1)	T-stat	-4.59		-4.08	-3.80		-3.07
	T-critic	-3.00		-3.00	-3.00		-1.96
Stationarity		Level One	Level	Level one	Level one	Level	Level one
Test critical values : 5%							

Source: Prepared by the researcher based on Eviews 12 outputs

Table 2 shows that some variables are stable at level L(0) and others are stable at level L(1). Therefore, we cannot apply the multiple linear model using the OLS method and will resort to a more accurate model, which is the Autoregressive Distributed Lag (ARDL) model.

3.2.3 Model Formula:

$$\begin{aligned}
 CO2Et = C_t + \lambda t + \sum_{i=1}^p \beta_1 CO2E_{t-i} + \sum_{j=1}^q \beta_2 ALTEN_{t-j} + \sum_{k=1}^r \beta_3 FDI_{t-k} \\
 + \sum_{m=1}^s \beta_4 GDP_{t-m} + \sum_{n=1}^t \beta_4 MFGG_{t-n} + \sum_{r=1}^u \beta_5 RDGDP_{t-r} + \varepsilon_t
 \end{aligned}$$

After processing the data on Eviews, we extracted the best model that could explain the trend of cleaner products, which was (1,0,0,1,0,1,2) ARDL with a constant and a time trend.

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Table 3. Table of feature estimates

Variable	Coefficient	Std. Error	t-Statistic	Prob
CO2E(-1)	1.142896	0.332379	3.438537	0.0055
ALT_EN	42.12596	60.44321	0.696951	0.5003
FDI	-0.343369	0.811785	-0.422981	0.6805
GDP	1.06E-10	4.64E-11	2.290255	0.0428
MFG_G	-0.048559	0.155788	-0.311702	0.7611
MFG_G(-1)	0.201436	0.136172	1.479278	0.1671
RD_GDP	0.442272	2.618227	0.168920	0.8689
RD_GDP(-1)	8.799179	4.922606	1.787504	0.1014
RD_GDP(-2)	-5.122408	3.242127	-1.579953	0.1424
C	-39.83732	41.16810	-0.967674	0.3540
@TREND	-1.816674	2.100506	-0.864874	0.4056

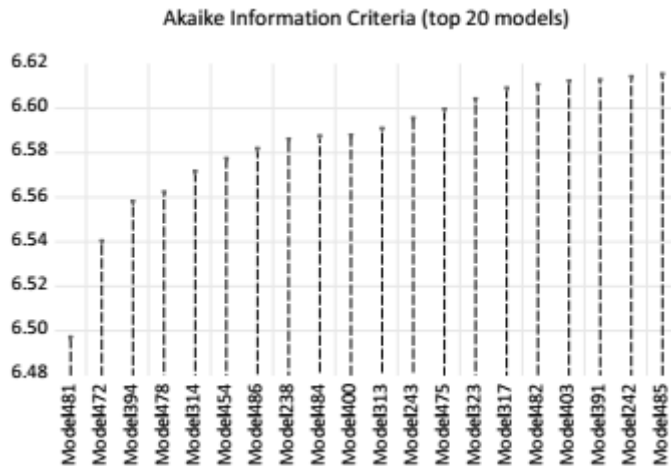
Source: Prepared by the researcher based on Eviews 12 outputs

The estimated equation for the autoregressive gap model (1998) is:

$$\begin{aligned}
 CO2E_t = & -1.9373 - 0.1394t_t + 1.1429CO2E_{t-1} - 2.1426ALT\ EN_t \\
 & - 0.3055FDI_t - 1.06 \times 10^{-10}GDP_t - 2.07 \times 10^{-10}GDP_{t-1} \\
 & - 0.2368MFG\ G_t + 0.2838RD\ GDP_t - 2.8168RD\ GDP_{t-1} \\
 & - 1.9484RD\ GDP_{t-2}^2
 \end{aligned}$$

a. Testing the optimal slowdown periods for the estimator model:

Fig.2. Akaike test for selecting model testing intervals.



Source: Eviews 12 output

The best model identified by the program is Model481: ARDL(1, 0, 0, 0, 1, 2) using the Akaike test, which selects the lowest Akaike value.

Model analysis:

Table 4. Model testing results

R-squared	0.986503	Mean dependent var	140.0144
Adjusted R-squared	0.974233	S.D. dependent var	33.29168
S.E. of regression	5.343976	Akaike info criterion	6.496670
Sum squared resid	314.1389	Schwarz criterion	7.042191
Log likelihood	-60.46337	Hannan-Quinn criter	6.625178
F-statistic	80.40077	Durbin-Watson stat	2.309205
Prob(F-statistic)	0.000000		

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

The R-squared = 0.98653 shows that the model is excellent for explaining the change in CO₂E, which was confirmed by the Adjusted R-squared = 0.97233. As for the autocorrelation of the residues, there is no correlation, as shown by the Durbin-Watson test = 2.309. As for the significance of the model, a single slowdown score for CO₂E was very significant, which means that there is a long-term relationship for this variable. The time trend shows a gradual downward trend in CO₂E. There are some non-significant variables, and this is due to the characteristics of the ARDL model because of the degrees of slowdown

An economic analysis of the model's features:

These analyses provide insight into Algeria's focus on cleaner products, public health, and the environment. The time trend coefficient $\lambda = -0.139$ indicates that Algeria is striving to reduce carbon dioxide emissions. This demonstrates its pursuit of clean technologies and its efforts to transform its economy into an environmentally friendly one, as evidenced by its renewable energy program and the closure of some polluting factories, setting environmental conditions for new projects and applying environmental standards such as ISO14000 contributes to producing cleaner products. Through the renewable energy index, we have observed that the relationship is inverse: the more alternative energy is used, the less pollution there is. Through the foreign investment index, we have observed that Algeria's goal is to attract environmentally friendly investments with environmentally friendly technology. As for the gross domestic product, its coefficient is not significant, and this is due to the instability of economic growth for several reasons, and it does not depend on heavy industries that pollute the environment. As for the industrial coefficient in Algeria, and its negative sign, it indicates that Algeria depends a lot on gas and oil exploration companies, and historically Algeria did not depend on manufacturing industries. Finally, through the general curve of state spending on research and development, we note that at the beginning this is what the research and development spending coefficient indicates.

ARDL Bounds Test Methodology (2001):

Long-Run Equation:

$$CO2E_t = -294.8013ALT_EN_t + 2.4029FDI_t + 1.06GDP_t \\ - 1.0698MFG_G_t - 28.8254RD_GDP_t$$

Therefore, we define the error term in time $t-1$ as:

$$EC_{t-1} = CO2E_{t-1} - CO2E_{t-1}(LR) \\ EC_{t-1} = CO2E_{t-1} - (-294.8013ALT_EN_{t-1} + 2.4029FDI_{t-1} \\ + 1.06GDP_{t-1} - 1.0698MFG_G_{t-1} - 28.8254RD_GDP_{t-1})$$

Short-Run ECM Equation:

$$\begin{aligned}\Delta CO2E_t = & -39.83732 - 1.816674TREND_t + 0.142896 \Delta CO2E_{t-1} \\ & + 0.152877 \Delta MFG_{G_{t-1}} + 4.119043 \Delta RD_{GDP_{t-1}} \\ & - 0.048559 \Delta MFG_{G_t} + 0.442272 \Delta RD_{GDP_t} \\ & + 5.122408 \Delta RD_{GDP_{t-1}}^2 - \lambda EC_{t-1}\end{aligned}$$

The Fisher test results (F-stat = 4.9), exceeding the upper limit at the 5% level, lead us to reject the null hypothesis due to the lack of a long-term equilibrium relationship between the variables and accept the alternative hypothesis.

b-Standard effect of each independent variable on cleaner product and carbon intensity:

Renewable/Alternative Energy ALT_EN: We observe that increased use of alternative energy sources is associated with a strong decrease in CO₂ emissions. Replacing polluting energy sources with cleaner ones reduces environmental pollution. This is due to the government's policy of supporting renewable energy projects.

Foreign Direct Investment (FDI): A positive indicator means that an increase in FDI levels is associated with a long-term increase in CO₂. This explains the situation of foreign investment in Algeria, which is concentrated in the energy, construction, mining, and manufacturing sectors, all of which are polluting.

Gross Domestic Product (GDP): The estimation results indicated that the coefficient of Gross Domestic Product (GDP) was positive, suggesting a potential positive relationship between economic growth and the level of cleaner production. However, this effect was not statistically significant, indicating that economic growth in Algeria does not necessarily translate into a tangible improvement in environmental performance. This can be attributed to the rentier nature of the Algerian economy, which relies heavily on the hydrocarbon sector, as well as the limited progress toward a green economy, During this period.

Growth in the Industrial/Manufacturing Sector (MFG_G): A negative coefficient indicates that industry in Algeria is not highly polluting, and the development of the industrial sector is based on low-pollution activities.

Research and development expenditure as a percentage of GDP:

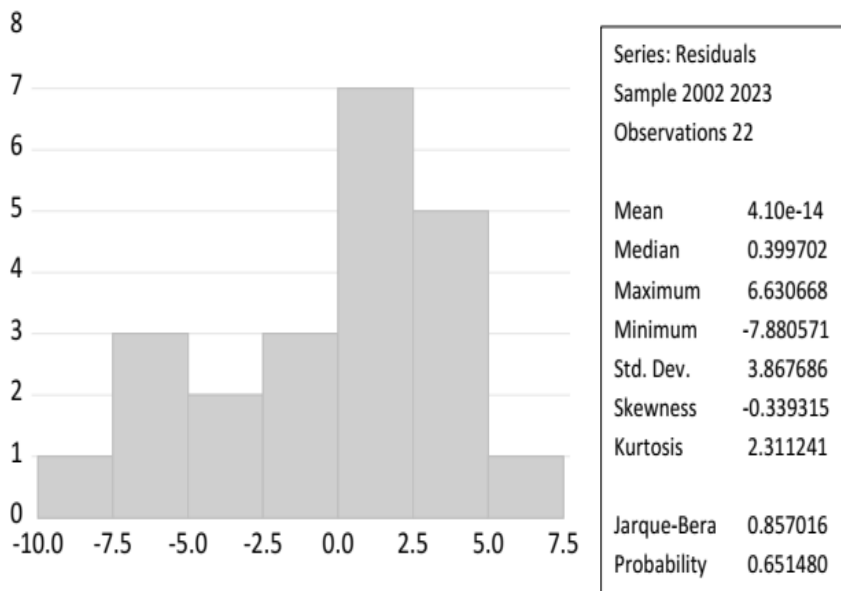
a negative coefficient in the equation, which explains why increased spending on research and development reduces emissions in the long run and leads to improved energy efficiency, cleaner technologies, or less polluting industrial processes.

From the study, we observed that, in Algerian data for the period 2000–2023, renewable/alternative energy (ALT_EN) and R&D spending as a percentage of GDP (RD_GDP) have a long-term impact. Promoting renewable energy and R&D spending as a percentage of GDP leads to significant emissions reductions and increases support for cleaner products.

4. Model Tests

4.1 Model Normality Test:

Fig.3. Model Normality Test



Source: Eviews 12 outputs

From the figure, we can see that the model residuals follow a normal distribution. Probability = 0.651480

4.2 Autocorrelation test for errors:

Table 5. Brioche–Godfrey chain correlation (LM) test

Breusch–Godfrey Serial Correlation LM Test:

Null hypothesis: No serial correlation at up to 2 lags

F-statistic	1.386240	Prob. F(2,9)	0.2987
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Source: From Eviews 12 outputs

The model does not suffer from autocorrelation of errors because

$$F\text{-stat}=0.2987>F\text{-tab}=0.05$$

4.3 Adaptation Instability Test:

Table 6. ARCH Adaptation Instability Test

Heteroskedasticity Test: ARCH

F-statistic	2.25E-06	Prob. F(1,19)	0.9988
Obs*R-squared	E-062.48	Prob. Chi-Square(1)	0.9987

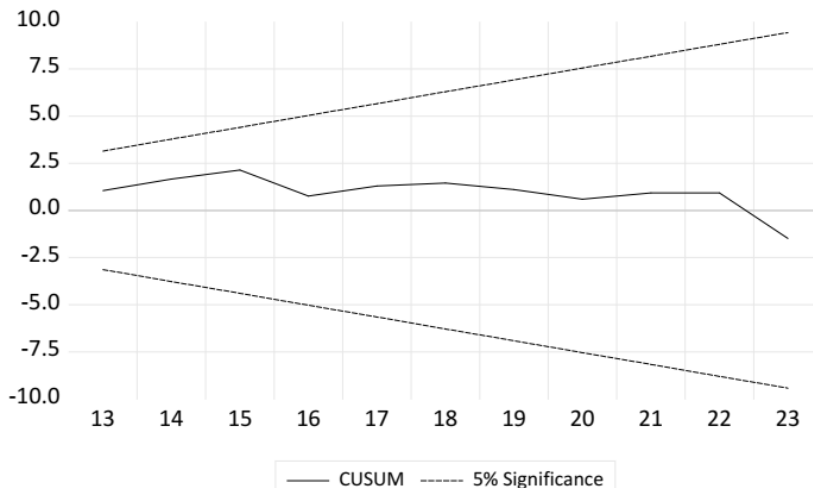
Source: Eviews 12 output

The model does not suffer from variance instability because

$$F\text{-stat}=0.2987>F\text{-tab}=0.05$$

4.4 Structural stability test of model parameters

Fig.4. CUSUM test for structural stability



Source: Eviews 12 output

The figure shows that the trend is within the boundaries, indicating structural stability of the model parameters

5. Conclusion

Through this study, we focused on the indicators (determinants) of cleaner products that have the greatest impact on achieving sustainable development, public health, and environmental protection. Studying this topic is among the most important issues, both now and in the future, as it is a fundamental pillar for achieving environmental, economic, and health (human) balance, because it aims to improve the quality of production

We noted that in Algeria there is a large group of economic and environmental factors affecting cleaner production, from which we took the most prominent and closest to achieving the study's objectives, and we studied them statistically and historically to answer the hypotheses put forward at the beginning of the study.

Answering the hypotheses:

There is a positive relationship between economic growth and cleaner production in Algeria.

Through our econometric study, we observed a relationship between carbon intensity (CO_2) and three variables: Industrial Value Added (MFG), Foreign Direct Investment (FDI), regarding Gross Domestic Product (GDP), although its coefficient was not statistically significant, it was retained in the model due to its theoretical importance in explaining the relationship between economic growth and cleaner production, and to avoid the potential bias that could result from omitting an important variable. These three statistical indicators represent both economic growth and carbon intensity (CO_2), which reflects the level of cleaner production. In this context, higher carbon intensity indicates a less clean product, whereas lower intensity reflects a cleaner product;

Increased energy consumption and carbon emissions lead to a decrease in cleaner production.

This is what we concluded from the relationship between carbon intensity (CO_2) and the share of renewable and nuclear energy in total energy (ALT_EN). It is inversely proportional to the consumption of polluting energy; the greater the demand for clean energy, the lower the demand for polluting energy, and the greater the cleaner production.

Spending on research and development contributes to improved environmental performance and cleaner products.

A benchmark study confirmed the relationship between carbon intensity (CO₂) and R&D spending (RD_GDP), validating this hypothesis. Cleaner products are inextricably linked to R&D; the two increase and decrease together.

This study presented a standard and economic analysis of the relationship between cleaner products and several economic and environmental variables in Algeria. Using documented data, the best autoregressive lag time gap (ARDL) model (1, 0, 0, 0, 1, 2) was identified, with model hypothesis testing and an interpretive time analysis of the results.

Among the proposals we came up with is that Algeria has an opportunity to be among the first countries to adopt an economic policy that increases cleaner production and reduces the health, environmental and economic problems that negatively affect sustainable development. It should accelerate the acquisition of clean technology and alternative energy, and increased spending on research and development, as well as the pursuit of international standards for environmental protection.

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