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Carbon Footprint and International Trade: An Econometric Study of Carbon Emissions Embodied in Algerian Exports 1990-2024.

ARGILLOS Amal
Oran graduate school of economics (Algeria), argiamal@gmail.com

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Abstract:

The objective of this research is to shed light on the carbon footprint, its indicators, and how it is measured. It will also address the impact of trade on greenhouse gas emissions and carbon embedded in exports. To do so, it will adopt a descriptive analytical approach to clarify the general framework of the carbon footprint and carbon embedded in exports. A standard analytical approach will be adopted in line with the requirements of the curriculum and the challenges posed.

One of the main findings of this research is that the fuel sector is responsible for more than 70% of total carbon emissions contained in exports. Furthermore, the current diversity of exports is insufficient to reduce emissions, since export diversification variable has not had a significant negative impact on contained emissions.

Key Words: *carbon footprint, carbon emissions, exports, international trade, embedded emissions.*
JEL Classification: *Q52 - Q57*

1. *Introduction*

Global concerns about greenhouse gas emissions, particularly carbon dioxide, increased over the past few decades, resulting in stronger commitments to climate change mitigation and greenhouse gas emission reductions. Most environmental policies have mainly focused on domestic emissions linked to production, often neglecting carbon emissions embedded in international trade flows, specifically exports. Nevertheless, international trade can effectively transfer emissions from importing countries to exporting countries, an effect that is exacerbated by disparities between countries in terms of environmental regulation, technological development, and energy efficiency.

Growth in exports, particularly in energy-intensive sectors, can significantly increase the carbon footprint of exporting countries. Although researchers are paying more attention to this, the direction and size of the relationship between exports and embedded carbon emissions are still up for debate, particularly in developing economies where production structures are often more carbon-intensive and environmental governance frameworks are still evolving. It raises a crucial question: How does international trade affect the carbon footprint embedded in exports?

This study seeks to provide a comprehensive overview of export-related carbon emissions through its theoretical framework and to highlight the relationship between international trade and these emissions. It explains how to measure the carbon footprint of exports and demonstrates how they contribute to increasing the carbon footprint of exporting countries. Also, it examines how this is impacted by income levels.

This question is addressed using a combined descriptive, analytical, and econometric approach. Official statistical data from international sources, including the World Bank and the International Energy Agency, are used to construct an empirical model that quantifies the relationship between exports and embodied carbon emissions. Through this methodology, our research aims to provide robust evidence on the real environmental cost of international trade and generate findings that support the development of more integrated trade and environmental policies.

2. *LITTERATURE REVUE*

Previous studies on environmental footprints and carbon footprints have examined these indicators as key measures for assessing environmental sustainability and their role in promoting sustainable development. Bedi (2021) emphasized the importance of the ecological footprint as an essential indicator for assessing sustainability, highlighting the need to reduce it in order to achieve long-term environmental balance. This study revealed that measuring the ecological footprint has promoted the adoption and dissemination of clean technologies, thereby encouraged a more rational use of natural resources and contributed to environmental balance.

Similarly, Baraji and Al-Zain Omran (2022) examined the conceptual framework and structural components of the ecological footprint and analyzed its relationship with indicators of progress toward sustainable development in Algeria. Their findings show that Algeria has a high carbon footprint, largely due to its heavy reliance on fossil fuels and the export of crude hydrocarbons. Evidence suggests that this model increases environmental pressure without

generating proportional improvements in development performance.

Khatouf (2025) reviewed key green technologies and their effectiveness in reducing carbon emissions, while examining Algeria's experience and future prospects in this area. It identified carbon footprinting as a key tool for assessing sustainability performance and confirmed the important role of green technologies in reducing emissions and transitioning to carbon neutrality. While Algeria was found to have significant potential in renewable energy and carbon capture technologies, the gap between available capacity and practical implementation was highlighted as a major obstacle slowing progress toward 2030-2050 environmental goals.

Taken together, these studies point to a clear consensus on the relevance of green indicators and carbon footprints as essential tools for assessing sustainability. In addition, they highlight the environmental challenges facing Algeria and identify green technologies as a key pathway for mitigating these challenges. As such, this set of publications provides a solid theoretical and empirical basis for the present study, broadening the debate by focusing specifically on carbon emissions embodied in exports and their relationship with international trade dynamics (Mechiche.Z, 2024).

1. The Concept of the Carbon Footprint

1.1 Definition of the Carbon Footprint

A carbon footprint is an indicator used to assess the environmental impact of a particular activity, with a particular focus on the greenhouse gas emissions associated with that activity. It can also be applied at different levels, starting with individuals based on their lifestyle, families, companies based on their activities, specific regions, or even specific products. Counting the carbon footprint helps to estimate the impact of each of these elements more accurately on total greenhouse gas emissions, which promotes awareness and actions aimed at reducing environmental impact, especially in the context of civil society organizations' activities (Training, 2025).

A carbon footprint is a measure indicating the amount of greenhouse gases emitted from daily activities in factories and companies, especially carbon dioxide resulting from energy and fuel consumption in production processes. These emissions directly affect global warming and climate change. Measuring and managing carbon footprints contributes to enhancing operational efficiency, reducing production costs, and improving the reputation of the factory. In addition, there is a global trend toward stricter measurement and management of these emissions, making compliance a market requirement.

Carbon footprint: An indicator for expressing the amount of carbon dioxide emissions resulting from any activity, whether by individuals, institutions, companies, or countries, by tracking the production or manufacturing processes of a specific product or the provision of a specific service at all stages, the raw materials from which it is made and the materials resulting from it, as well as how those products will be disposed of in the future ((NQI), 2025)

It can be viewed as the sum of emissions produced by an individual, institution, or country as a result of energy consumption and reliance on transportation and various economic activities (Khattouf, 2025)

1.2 Carbon footprint indicators:

A) The Primary carbon Footprint: An indicator that measures the amount of carbon dioxide emissions resulting from the burning of fuels. and reflects our energy consumption in various activities such as transportation, including cars, ships, and airplanes. It is an indicator that enables us to identify daily activities that constitute a significant portion of emissions.

B) The secondary carbon footprint is an indicator that measures the indirect carbon dioxide emissions resulting from the life cycle of the products we use, from the extraction of raw materials to manufacturing, and finally to consumption and distribution. This indicator is mainly related to manufacturing processes, meaning that the more manufactured products we consume, the greater the amount of carbon dioxide emissions (Retrieved, 2023).

1.3 Methods of measuring carbon footprint

Carbon footprint measurement is the first step towards reducing it, as it allows us to accurately determine the volume of emissions and identify the most impactful activities or processes. It helps to set realistic reduction targets and plans, and at the same time contributes to improving operational efficiency and reducing energy and raw material costs. Moreover, businesses that commit to measuring their carbon footprint often enhance their environmental reputation and improve their chances of complying with international standards such as the Greenhouse Gas Protocol.

Fig1. Steps for Calculating the Carbon Footprint



Source: (decarboact, 2025)

A) Individual level measurement:

- The individual begins by calculating their electricity, gas, and water consumption using their utility bills, then converts this into carbon dioxide emissions equivalents using emission factor tables issued by the relevant authorities.
- Next, the impact of daily travel is estimated by calculating the distances traveled by private car or public transport and multiplying them by the emission factors per kilometer.
- In terms of nutrition, the amount of meat, dairy products, vegetables, and other foods is estimated and converted into equivalents that reflect the emissions associated with their

production and transport.

- For shopping and waste, the impact of the production of goods and consumer materials associated with disposal or recycling is taken into account.

B) Measurement at the company and facility level

Company emissions are divided into three main stages according to the GHG Protocol framework.

- Phase 1 includes direct emissions from sources owned or directly controlled by the facility, such as fuel engines and boilers.
- Phase 2 covers indirect emissions related to electricity, heat, or cooling consumption rates.
- Phase 3 extends to all other indirect emissions, such as supply chains, employee travel, and waste management.

For an accurate estimate, companies use the ISO 14064 standard and specialized software such as SimaPro and Life Cycle Assessment (LCA) Software to conduct an annual emissions estimate.

c) Measurement at the industrial sector level

In the context of manufacturing plants, production lines and raw material flows are first analysed to identify hot spots of high energy and thermal consumption.

Emissions factors appropriate for each type of fuel or thermal or chemical process are then selected.

A significant number of large factories rely on continuous emission monitoring systems linked to the facility's environmental management system, enabling periodic reporting on actual emission rates and comparison with annual targets.

1.4 Carbon footprint measurement and tracking tools and software

Specialized commercial software for comprehensive life cycle assessment (LCA) is available on the market, such as SimaPro, as well as environmental sustainability management platforms such as Enablon and Intelex.

Open-source solutions such as OpenLCA for life cycle footprint calculations and GHG Protocol tool calculations are also available, along with practice guides issued by international agencies such as the International Energy Agency (IEA) and the United Nations Environment Programme (UNEP) (Emam, 2025)

1.5 International trade and carbon emissions

A) Pollution Haven Hypothesis.

An economic hypothesis that states that polluting companies move from countries with strict environmental regulations (such as developed countries) to countries with less stringent regulations in order to reduce production costs and take advantage of a less restrictive

environment, leading to a concentration of pollution in developing or less regulated countries. Despite being a popular idea, studies on this topic are conflicting. Some recent research using panel data supports it, especially in emerging economies, while other studies point to the complexities and varying effects of global trade on emissions.

Key points of the theory

1. Environmental standards disparity: There are significant differences in the strictness of environmental laws between countries.
2. Cost impact: Strict regulations increase production costs.
3. Industrial migration: Polluting industries (such as energy and steel) move to countries with low environmental costs.
4. Result: Increased pollution in host countries (pollution havens) and decreased pollution in home countries.

B) The environmental comparative advantage hypothesis.

Environmental comparative advantage suggests that countries can achieve economic gains from international trade by specializing in the production of goods and services that use their natural resources (such as water and land) more efficiently, thereby reducing environmental pressures and helping to achieve food security. , but trade can generate negative environmental impacts (pollution, resource depletion) and requires sustainable management and the application of environmental standards to ensure mutual benefit for all.

The concept of comparative advantage in the context of the environment:

- Theoretical basis: Based on David Ricardo's theory, where countries specialize in producing what they have a comparative advantage in (lower opportunity cost).
- Environmental application: Countries with abundant water resources specialize in agriculture, and countries with suitable climates specialize in certain crops, taking advantage of the efficient use of natural resources (land, water, energy).
- Channels through which trade affects emissions (trade volume, export composition, technology).

Trade affects emissions through (trade volume (increased production and transport (export composition (shift towards carbon-intensive or environmentally friendly industries and technology innovation cleaner production processes, logistical efficiency, and the emergence of new products. Trade expansion and increased volume lead to more emissions, while a shift towards lower-carbon value-added exports and the application of green technologies can reduce the carbon footprint. The final impacts depend on the balance between these channels and the policies pursued.

1.6 Channels through which trade affects emissions

a) Scale Effect:

1. Increased production: Trade growth means increased demand, which necessitates increased production, and thus increased consumption of energy and resources, and increased emissions (especially from heavy industries and factories).
2. Transportation and logistics: Increased movement of goods by sea, air, and land freight

raises fossil fuel consumption and thus emissions.

b) Composition Effect:

1. Change in production structure: If a country focuses on exporting carbon-intensive products (such as steel, cement, and energy), the exporting country's emissions will increase. The opposite is true when importing or exporting environmentally friendly products.
2. Emissions dumping: Developed countries may "dump" their emissions by transferring polluting industries to developing countries, which increases the latter's emissions and reduces the former's, but global emissions remain the same or increase.

C) Technology and efficiency (Technique Effect):

1. Technology transfer: Trade accelerates the spread of clean technologies and innovations (such as electric cars, automation, 3D printing) that reduce energy consumption and emissions.
2. Efficiency improvements: Technology helps improve production and transport efficiency (e.g., shipping containers, smart supply chains), reducing the carbon footprint per unit of production.
3. Green transition: Trade encourages investment in renewable energy and sustainable technologies, leading to a green economy.

1.7 Embodied carbon in exports

Definition of the concept: Embodied carbon is the total greenhouse gas emissions resulting from the production of a good, including the extraction of raw materials, manufacturing, transportation, and use. These emissions (direct and indirect) are calculated and incorporated into the product to be taxed or counted as part of climate targets, as in the European Union's Carbon Border Adjustment Mechanism (CBAM).

• Concept: Refers to the amount of greenhouse gases emitted (especially carbon dioxide) during the life cycle of a product, from extraction to consumer delivery. This concept focuses on the carbon footprint inherent in imported or exported goods.

- Embedded emissions: These include emissions resulting from:
- Production: energy consumption, manufacturing processes, and materials used.
- Transportation: shipping and distribution.
- Use: energy consumption during product use.
- Waste: disposal of the product at the end of its life.

1.8 Its importance in trade:

a) Carbon Border Adjustment Mechanism (CBAM): Imposed by countries such as the European Union on specific imports, where a tax is imposed on imported products equivalent to the domestic carbon price, based on the amount of carbon embedded in their production, to avoid "carbon leakage" abroad.

b) Environmental impact measurement: It helps companies and countries understand the carbon footprint of their exports and calculate indirect emissions.

Embedded carbon is all greenhouse gases that are "trapped" inside a product and released when it is produced, becoming part of its commercial value when exported.

1.9 The difference between domestic emissions and embodied emissions

The main difference is that domestic (or direct Scope 1) emissions are greenhouse gas emissions that are emitted directly by the company or that it owns and controls.

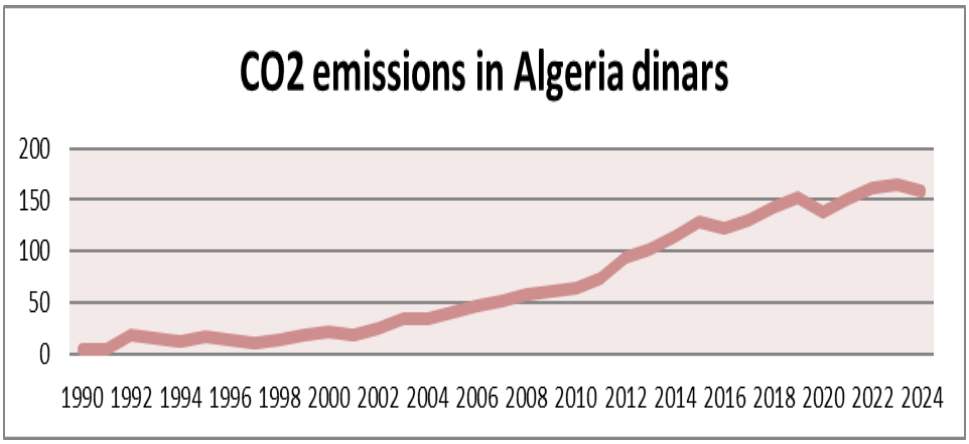
Embodied emissions are greenhouse gas emissions generated throughout the value chain of a given product, from raw material extraction to production and final delivery, even if they occur outside the company's direct control, and are calculated to determine the carbon footprint of the product itself (such as those calculated for the European Carbon Border Adjustment Mechanism (CBAM) (Gruenig, 2023)

1.10 Algeria's Carbon Footprint

Algeria has experienced a steadily rising carbon footprint, compounded by an ecological deficit that emerged in the 1970s. This deficit reached approximately 1.9 hectares per capita in 2016, down from 2.5 hectares in 2014, yet continues to grow. In global rankings, Algeria placed 35th out of 187 countries for total ecological footprint in 2016.

However, 2020 witnessed a decline in carbon dioxide emissions—and thus the carbon footprint due to reduced energy and resource use amid economic constraints from the COVID-19 pandemic. Emissions peaked at 10.34 million tons in 1997, fluctuated upward to 151.78 million tons in 2019, dipped in 2020 due to economic shutdowns, then rebounded with global recovery, reaching a high of 164.11 million tons in 2023. Emissions from conventional energy sources stood at approximately 129 million tons in 2015, with an annual increase of about 0.4%.

fig 2. The volume of carbon dioxide emissions in Algerian dinars during the period 1990-2024



Source: Prepared by the researcher based on World Bank statistics.

2.THE EMPIRICAL STUDY

This section of the study aims to estimate the volume of embodied carbon emissions in Algerian exports and to analyse their relationship with export volume, per capita gross domestic product, energy consumption, and imports of petroleum resources. The analysis employs annual time-series data spanning from 1990 to 2024, utilizing the econometric software EViews.

2.1. The Study Model and Variables

To uncover the true magnitude of embodied carbon emissions in Algeria’s exports, superficial analysis is insufficient; a robust econometric framework grounded in the modified STIRPAT model is required, as it represents the most scientifically sound approach for examining the environmental impact of economic activities. To investigate this complex relationship, annual time-series data were employed, capturing major transformations in the

Algerian economy from 1990 to 2024. Embodied carbon emissions in exports are treated not as an isolated figure but as a dependent variable that responds dynamically to fluctuations in export volume and energy intensity. To provide a comprehensive picture, per capita gross domestic product and imports of petroleum resources were also incorporated. By constructing a logarithmic model to represent these interactions, the following study model was derived:

$$\mathrm{Ln}(\mathrm{CO2_{exp}}) = \beta_0 + \beta_1\,\mathrm{Ln}(\mathrm{EXP_t}) + \beta_2\,\mathrm{Ln}(\mathrm{GDP_t}) + \beta_3\,\mathrm{Ln}(\mathrm{EC_t}) + +\beta_4\,\mathrm{Ln}(\mathrm{OIL_t})$$

where:

- $\mathrm{EMBCO2_t}$: Embodied carbon emissions in exports.
- $\mathrm{EXP_t}$: Export volume.
- $\mathrm{GDPPC_t}$: Per capita gross domestic product.
- $\mathrm{ENCON_t}$: Energy consumption.
- $\mathrm{OILIMP_t}$: Imports of petroleum resources.

2.2 Estimation Method

To achieve the objectives of this study, the Autoregressive Distributed Lag (ARDL) model was employed. This approach is a well-established econometric technique for analysing both short- and long-run relationships among economic variables. Its key advantages include:

- The ARDL model does not require all variables to be integrated of the same order (provided none are I(2).
- It incorporates a sufficient number of lags to derive the optimal specification from a general unrestricted model.
- It yields reliable results even with small sample sizes and facilitates straightforward estimation of cointegration relationships using ordinary least squares.
- It allows differentiation between endogenous and exogenous variables.

3. Analysis and Discussion of Results

3.1. Multicollinearity Test Between Variables

To ensure the absence of severe multicollinearity among the independent variables, which could compromise the accuracy and efficiency of the regression estimates simple correlation coefficients and the variance inflation factor (VIF) were examined. The results of these tests are presented in Table 1.

Table 1. Results of Correlation Analysis and Variance Inflation Factor (VIF)

Correlation Matrix				
	EXP	GDP	EC	OIL
EXP	1			
GDP	0.04822	1		
EC	-0.2763	0.8509	1	
OIL	0.9072	0.3804	0.0156	1
Variance Inflation Factor (VIF)				
	EXP	GDP	EC	OIL
	22.9219	11.1748	6.3527	16.8315

Source: Prepared by the researcher based on EViews 12 output.

The correlation matrix reveals relatively high correlations among certain independent variables, particularly between export volume and petroleum resource imports. This is corroborated by VIF values that, in some cases, exceed the conventionally accepted threshold, indicating the presence of multicollinearity. However, this degree of collinearity is not severe enough to invalidate the estimation, especially within dynamic modelling frameworks. Accordingly, the observed multicollinearity does not preclude the application of the Autoregressive Distributed Lag (ARDL) model, which leverages temporal structure and lagged terms to accommodate inter-variable relationships.

3.2. Stability tests for variables:

Testing the stability of time series is a necessary and important condition for estimating the relationship based on the model (ARDL), as all variables must be integrated of zero or first order without exceeding that. Using the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test, the results shown in Table (2) were obtained.

Table 2. Stability test for study variables

Variable	ADF Test (Level)		ADF Test (First Difference)		PP Test (Level)		PP Test (First Difference)	
	t-Statistic	Prob.	t-Statistic	Prob.	t-Statistic	Prob.	t-Statistic	Prob.
EMBCO2	-1.7979	0.6835	-5.3298	0.0007	-1.7710	0.6965	-5.3011	0.0007
EXP	-2.1517	0.4999	-6.7666	0.0000	-2.0800	0.5380	-9.8166	0.0000
GDPPC	-2.0267	0.5663	-5.2557	0.0008	-2.3260	0.4095	-5.2580	0.0008
ENCON	-2.7940	0.2093	-6.8658	0.0000	-2.7503	0.2245	-6.8468	0.0000
OILIMP	-2.0157	0.5702	-5.7396	0.0003	-1.9521	0.6035	-7.5846	0.0000

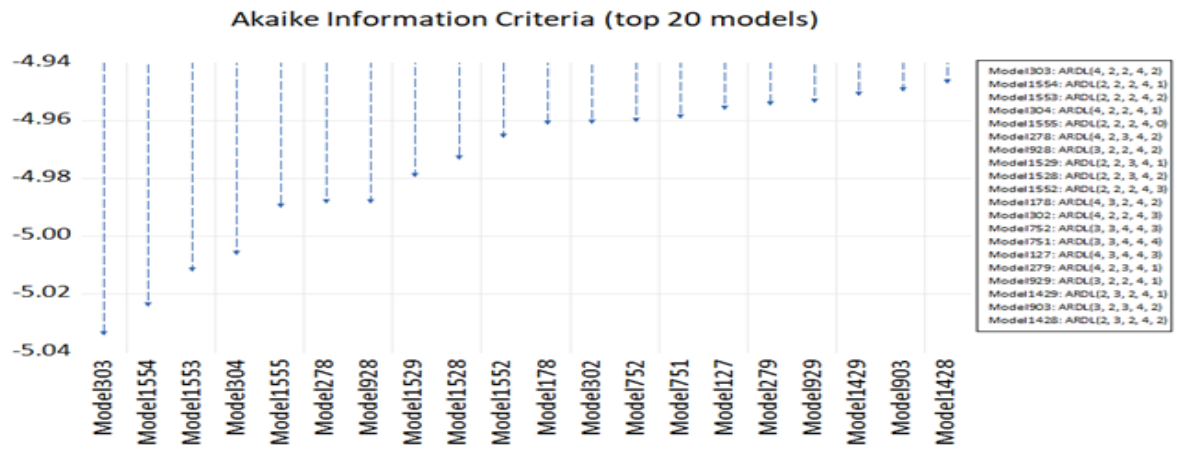
Source: Prepared by the researcher based on EViews 12 output.

Results from the Dickey-Fuller and Phillips-Perron tests reveal that all variables are stationary when using first differences, as the series show statistical stability at a high significance level in both tests. The consistency of the ADF and PP test results confirms that all variables are integrated of order (1) I, providing a reliable normative basis for the use of dynamic regression models (especially ARDL models) and avoiding the problem of spurious regression.

3.3. Determining the optimal lag periods

In order to select the optimal lag period for the variables in the model, we rely on the AKAIC (AIC) criterion. As shown in Figure 2, the results indicate that the optimal model is (4,2,2,4,2) ARDL.

Fig :3 Time lag periods



Source: Prepared by the researcher based on EViews 12 output.

3.4. Co-integration Testing via the Bounds Test Approach

Co-integration refers to the correlation or compatibility between two or more time series. Statistically speaking, the existence of cointegration between variables indicates the existence of a long-term equilibrium relationship. The bounds test is used to estimate the cointegration relationship. Table 3 shows the results of the cointegration test.

Table 3. Bounds Test Results

F-Bounds Test		
Test Statistic	Value	K
F- Statistic	5.449	2
Critical value Bounds		
Significance	I(0)Bounds	I(1)Bounds
10%	2.20	3.09
5%	2.56	3.49
2.5%	2.88	3.87
1%	3.29	4.37

Source: Prepared by the researcher based on EViews 12 output.

The computed F-statistic of 5.449 exceeds the upper critical bounds at the 1%, 2.5%, 5%, and 10% significance levels. Consequently, the null hypothesis of no cointegration is rejected, confirming the existence of a long-run equilibrium relationship among the variables.

3.5. Model Estimation using the ARDL Approach

Table 4 presents the estimated relationship with embodied carbon emissions in exports as the dependent variable and export volume, per capita GDP, energy consumption, and petroleum resource imports as independent variables.

Table4.ARDL Model Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
DLCO2(-1)	-0.748547	0.297711	-2.514343	0.0361
DLCO2(-2)	-0.525876	0.163509	-3.216182	0.0123
DLCO2(-3)	-0.235629	0.220608	-1.068089	0.3166
DLCO2(-4)	0.180890	0.179421	1.008185	0.3429
DLEXP	-0.022231	0.089952	-0.247148	0.8110
DLEXP(-1)	-0.131281	0.091810	-1.429924	0.1906
DLEXP(-2)	-0.205915	0.118494	-1.737765	0.1205
DLGDP	-0.080551	0.067364	-1.195751	0.2660
DLGDP(-1)	0.168153	0.056047	3.000215	0.0171
DLGDP(-2)	0.176021	0.067192	2.619667	0.0307
DLEC	0.365933	0.107101	3.416719	0.0091
DLEC(-1)	0.255235	0.130818	1.951069	0.0868
DLEC(-2)	0.404788	0.125565	3.223737	0.0122
DLEC(-3)	0.396263	0.160822	2.463987	0.0391
DLEC(-4)	0.244424	0.111178	2.198491	0.0591
DLOIL	0.044291	0.066745	0.663593	0.5256
DLOIL(-1)	0.082411	0.064086	1.285942	0.2344
DLOIL(-2)	0.073790	0.079646	0.926476	0.3813
C	-0.051048	0.012299	-4.150624	0.0032
R-squared	0.926048	Mean dependent var		0.012250
Adjusted R-squared	0.759658	S.D. dependent var		0.036213
S.E. of regression	0.017753	Akaike info criterion		-5.033490
Sum squared resid	0.002521	Schwarz criterion		-4.121605
Log likelihood	86.95212	Hannan-Quinn criter.		-4.762339
F-statistic	5.565499	Durbin-Watson stat		1.987936
Prob(F-statistic)	0.009132			

Source: Prepared by the researcher based on EViews 12 output.

The coefficient of determination (R^2) is 92%, indicating that the independent variables explain 92% of the variation in embodied carbon emissions in exports, with the remaining 8% attributable to other factors captured in the error term. The F-statistic of 5.57 exceeds its tabular value, reinforcing the model's explanatory power.

3.6. Results of Short-Run and Long-Run Relationship Estimation via the ARDL Methodology

The estimation results of the ARDL model, in both its long- and short-run dimensions, reveal a rich dynamic structure governing the behaviour of carbon emissions embodied in exports. The independent variables do not operate in isolation; rather, they exert varying effects in direction, magnitude, and timing. The results are presented in Table (5).

A. Results of estimating the long-run relationship between the variables according to the ARDL methodology:

At the long-run level, export volume (DEXP) appears to have a negative effect on carbon emissions, although this effect lies at the margin of statistical significance. This suggests that export expansion does not necessarily lead to sustained environmental pressure and may reflect gradual improvements in production efficiency or a shift in the export structure. In contrast, GDP per capita (DGDP) records a positive and statistically significant effect, indicating that economic growth, in its current form, remains associated with a rising carbon burden. Energy consumption (DEC) emerges as the most influential determinant, showing a strong and highly significant positive impact, thereby confirming the central role of energy in explaining emission dynamics. As for oil resource imports (DOIL), their weak statistical significance suggests that their long-term effect remains limited or indirect.

B. Results of estimating the short-run relationship between the variables according to the ARDL methodology

In the short run, a more complex picture emerges. While the immediate effects of some variables appear weak, their lagged values—particularly those related to exports (DEXP) and GDP (DGDP)—display significant temporal interactions, reflecting delayed rather than

instantaneous responses. Energy consumption (DEC) once again stands out as a key driver, with both its current and lagged effects showing high statistical significance, while an opposite sign appears that reflects a gradual adjustment in energy consumption behavior in the short term.The error correction term carries a negative sign and is highly statistically significant, confirming the existence of a long-run equilibrium relationship among the variables. It also indicates a high speed of adjustment, whereby short-run shocks are absorbed and the system returns to its equilibrium path within a relatively short period. This demonstrates the econometric consistency of the model and its capacity to explain carbon emission dynamics within the integrated framework of trade, growth, and energy.

Table 5. Results of estimating the short- and long-run relationship between the variables according to the ARDL methodology

Variable	Long-Run (Levels)	t-Statistic	Prob.	Short-Run(ECM)	t-Statistic	Prob.
DEXP	-0.1543	-2.19	0.0599	-0.0222	-0.44	0.6707
DEXP(-1)	—	—	—	0.2059	2.83	0.0221
DGDP	0.1132	3.85	0.0048	-0.0806	-1.83	0.1039
DGDP(-1)	—	—	—	-0.1760	-3.41	0.0092
DEC	0.7156	6.36	0.0002	0.3660	5.40	0.0006
DEC(-1)	—	—	—	-1.0455	-5.35	0.0007
DEC(-2)	—	—	—	-0.6407	-4.05	0.0037
DEC(-3)	—	—	—	-0.2444	-2.99	0.0172
DOIL	0.0861	1.72	0.1233	0.0443	1.20	0.2653
DOIL(-1)	—	—	—	-0.0738	-1.58	0.1534
Constant(C)	-0.0219	-4.66	0.0016	—	—	—
CointEq(-1)	—	—	—	-2.3292	-7.29	0.0001

Source: Prepared by the researcher based on EViews 12 output.

3.7. Diagnostic Tests of the Model

At this stage, a statistical evaluation of the model is conducted to verify whether the estimated specification is the most appropriate for assessing the relationship under study. The results of these tests are summarized in Table (6) below.

Table 6. Results of Diagnostic Tests of the Estimated Model

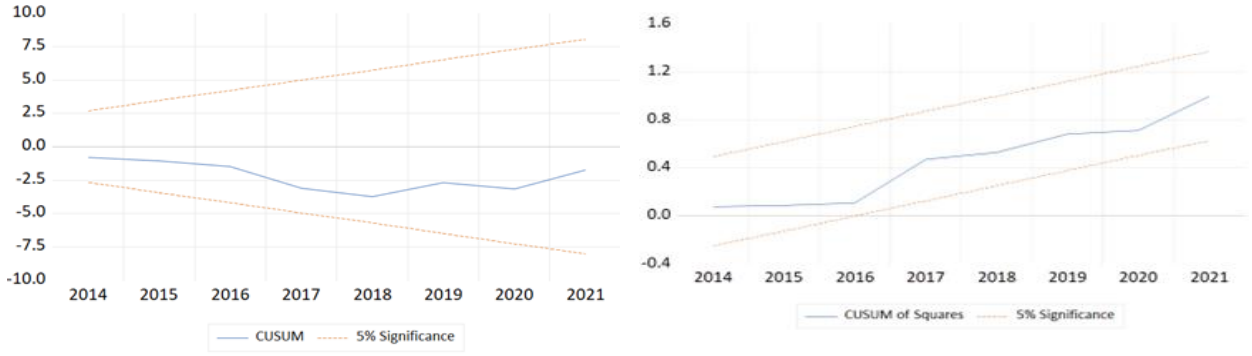
Diagnostic Test	Statistic	Value	Degrees of Freedom	Prob.
Breusch–Godfrey LM (Serial Correlation)	F-statistic	0.2976	(2,6)	0.7529
	Obs*R-squared	2.4369	$Chi^2(2)$	0.2957
ARCH (Conditional Heteroskedasticity)	F-statistic	0.9849	(1,24)	0.3309
	Obs*R-squared	1.0250	$Chi^2(1)$	0.3114
Jarque–Bera (Normality of Residuals)	JB statistic	1.1690	—	0.5574

Source: Prepared by the researcher based on EViews 12 output.

The results of the diagnostic tests presented above indicate that the estimated model is free from major econometric problems. The Breusch–Godfrey LM test shows no evidence of serial correlation in the residuals, whether based on the F-statistic or the Obs*R^2 statistic, as the probability values exceed the conventional significance levels. Likewise, the ARCH test confirms the absence of conditional heteroskedasticity, indicating the stability of the variance of the random errors. The Jarque–Bera test further reveals that the residuals follow a normal distribution. Therefore, it can be concluded that the model possesses sound statistical properties and that its results are suitable for econometric inference and analysis.

With regard to structural stability tests (CUSUM and CUSUMSQ), which are used to assess the stability of model parameters over time and detect potential structural changes, Figure (3) below shows that the model remains within the critical bounds in both tests. Accordingly, the null hypothesis that the model parameters remain stable over time is accepted. This also indicates consistency between the long-run and short-run results.

Fig 4. Results of Structural Stability Tests (CUSUM and CUSUMSQ)



Source: Prepared by the researcher based on EViews 12 output.

Main Findings of the Econometric Study

- A stable long-run relationship exists between embodied carbon emissions in exports and their economic determinants, implying that export performance carries cumulative environmental implications beyond mere trade outcomes.
- Per capita GDP serves as an indirect channel for growth-related environmental impact, with its positive coefficient signalling that income gains remain tied to energy-intensive production and consumption patterns.
- Energy consumption plays a decisive role in emission dynamics, reflecting heavy reliance on high-carbon conventional sources in export activities and highlighting deficiencies in current energy policies addressing environmental externalities.

4. Conclusion

This study has demonstrated that Algerian exports contribute substantially to elevating the national carbon footprint, primarily due to excessive reliance on hydrocarbons, which are characterized by high carbon emission intensity. This represents a significant challenge for economic policy, necessitating the adoption of a comprehensive sustainable strategy aimed at reducing the carbon footprint. Such a strategy should prioritize energy mix diversification, with a focus on exporting energy derived from renewable sources.

Furthermore, Algerian regulations seek to restrict gas flaring to exceptional cases only,

targeting a rate not exceeding 1% by 2030. Associated gas recovery programs have already achieved notable success in reducing flaring rates, lowering them from 5.43% in 2020 to 3.19% in 2022.

Key Findings

- A positive relationship exists between Algerian exports and embodied carbon emissions.
- The hydrocarbon sector accounts for 70% of total embodied carbon emissions in exports.
- Growth in gross domestic product exerts a positive and statistically significant impact on embodied carbon emissions in exports.
- Algeria possesses promising carbon capture capabilities that remain underutilized.

5.Bibliography List

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