

The Impact of Financial Sustainability on the Environmental Dimension of Sustainable Development: An Econometric Study Using Panel Data Models for Algeria and Selected Arab Countries (2004–2022)

Asma Aribi 

Abstract. *This study aims to assess the impact of fiscal sustainability on the environmental dimension of sustainable development in Algeria and a selected group of Arab countries over the period 2004–2022. To analyze the dynamic relationships among the variables, the study employs panel-data econometric models, particularly the Panel ARDL model. To identify the characteristics of the data and select the appropriate model, a series of preliminary econometric tests were conducted. The results revealed the existence of a long-run relationship and cointegration among the study variables. Furthermore, fiscal sustainability was found to have a significant impact on the environmental dimension of sustainable development. The nature of this impact varied between the short and long run, as well as across the countries under investigation. The findings highlight the importance of directing financial resources toward green investments, renewable energy, and environmental protection. The study recommends the implementation of integrated fiscal and environmental policies to ensure a balance between fiscal sustainability and sustainable development.*

Keywords: *fiscal sustainability, sustainable development, environmental dimension, panel data, Panel ARDL model, Algeria, arab countries*

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Maliyyə dayanıqlılığının davamlı inkişafın ətraf mühit ölçüsünə təsiri: Əlcəzair və seçilmiş ərəb ölkələri üçün Panel məlumat modellərindən istifadə edilmiş ekonometrik tədqiqat (2004–2022)

Asma Aribi 

Xülasə. *Bu tədqiqatın məqsədi 2004–2022-ci illər ərzində Əlcəzair və seçilmiş ərəb ölkələrində maliyyə dayanıqlılığının davamlı inkişafın ekoloji aspektinə təsirini qiymətləndirməkdir. Tədqiqatda dəyişənlər arasındakı dinamik əlaqələri təhlil etmək üçün panel məlumatları ekonometrik modellərdən, xüsusilə Panel ARDL modelindən istifadə edilmişdir. Məlumatların xüsusiyyətlərini müəyyən etmək və uyğun modeli seçmək məqsədilə bir sıra ilkin ekonometrik testlər aparılmışdır. Nəticələr tədqiqat dəyişənləri arasında uzunmüddətli əlaqənin mövcudluğunu və kointeqrasiyanın olduğunu göstərmişdir.*

Həmçinin, maliyyə dayanıqlığının davamlı inkişafın ekoloji aspektinə əhəmiyyətli təsir göstərdiyi müəyyən edilmişdir. Bu təsirin xarakteri qısa və uzunmüddətli dövrlər, eləcə də tədqiq olunan ölkələr arasında fərqlənmişdir. Nəticələr maliyyə resurslarının yaşıl investisiyalara, bərpa olunan enerjiyə və ətraf mühitin mühafizəsinə yönəldilməsinin vacibliyini göstərir. Tədqiqat maliyyə dayanıqlığı ilə davamlı inkişaf arasında tarazlığın təmin edilməsi üçün integrasiya olunmuş maliyyə və ekoloji siyasətlərin həyata keçirilməsini tövsiyə edir.

Açar sözlər: maliyyə dayanıqlığı, davamlı inkişaf, ekoloji aspekt, panel məlumatları, Panel ARDL modeli, Əlcəzair, ərəb ölkələri

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Introduction

Financial sustainability has become one of the fundamental pillars for achieving sustainable development, given its crucial role in enhancing governments' ability to manage financial resources efficiently, ensuring the sustainability of public finances, and maintaining a balance between revenues and expenditures while maintaining the rights of forthcoming generations (Abdelhadi, 2017). The notion of finance sustainability is no longer confined to preserving the stability of financial and economic indicators; instead, it has evolved into a broader concept encompassing the economic, societal, and ecological facets of sustainable development, particularly amid escalating global environmental Obstacles including climate change, rising greenhouse gas emissions, and the exhaustion of natural resources.

Sustainable development incorporates an environmental dimension that seeks to safeguard the environment while ensuring the responsible and sustainable utilization of natural resources. resources, and pollution reduction to ensure the sustainability of ecosystems and promote development for both present and future generations. In this context, sustainable fiscal policies have emerged as a vital instrument for supporting the transition toward a green economy by directing public expenditure toward environmental projects, promoting investment in renewable energy, developing sustainable infrastructure, and adopting fiscal and tax policies that encourage carbon emission reductions and improve resource-use efficiency.

Algeria, like many Arab countries, faces increasing challenges in balancing the requirements of financial sustainability with environmental protection. These challenges are largely driven by heavy dependence on oil revenues, fluctuations in energy prices, rising public debt levels, and growing pressure on public budgets. Consequently, these factors have affected governments' ability to finance environmental policies and implement programs aimed at achieving the Sustainable Development Goals (SDGs). This situation highlights the need to assess the link between financial sustainability and Sustainable development's environmental component, as well as the extent to which sound public financial management can mitigate environmental degradation and promote sustainable economic growth.

In recent years, the relationship between financial sustainability and the environment has attracted growing attention in the economic literature. Numerous studies have found that fiscal discipline, improvements in the structure of public revenues, rationalization of government expenditure, and efficient public debt management can contribute to enhancing environmental quality and reducing

carbon dioxide (CO₂) emissions. Conversely, other studies suggest that weak financial sustainability may lead to reduced spending on environmental protection and delays in environmental investments, thereby exacerbating environmental problems and hindering.

In light of this, the current study is to investigate how financial sustainability affects in Algeria and a few other Arab nations between 2004 and 2022. Panel data models are used in the this study investigates the dynamic relationships he interactions among the variables over time and across nations, identify both short-term and long-term effects, and provide empirical evidence to support policy recommendations for promoting environmental policies, bolstering financial sustainability, and advancing the attainment of sustainable development goals (SDGs).

Research Problem

Fiscal sustainability has become one of the fundamental pillars for ensuring macroeconomic stability and promoting sustainable development. It reflects the ability of governments to manage public resources efficiently, maintain the sustainability of public finances, and fulfill their current and future financial obligations without compromising the economic and financial. Concurrently, the environmental dimension of sustainable development represents one of the most pressing contemporary challenges, particularly in light of the increasing emissions of greenhouse gases, Natural resource depletion, and the growing consequences of climate change and environmental degradation.

Algeria and several Arab countries face interconnected challenges in this regard. Many of these economies remain, to varying degrees, dependent on oil revenues and are therefore vulnerable to fluctuations in energy prices. In addition, increasing pressures on public finances and rising government expenditure requirements may constrain the ability of governments to finance environmental policies and green investments. Consequently, fiscal sustainability should not be viewed solely as an economic and financial objective; it may also constitute an important factor influencing countries' capacity to put into practice environmental policies and advance sustainable development.

Despite the growing significance of the interrelationship between fiscal sustainability and environmental performance, the nature of this relationship remains insufficiently explored, particularly in the context of Algeria and selected Arab countries. This is especially relevant given the differences among these countries in terms of their economic structures, dependence on natural resources, fiscal conditions, and environmental and institutional policies. Accordingly, examining the extent to which fiscal sustainability can support the transition toward a more environmentally sustainable development pathway is of considerable academic and policy relevance.

In light of the foregoing, this study aims to examine the following central research question: What is the impact of fiscal sustainability on the environmental dimension of sustainable development in Algeria and selected Arab countries during the period 2004–2022?

Research Hypotheses

Main Hypothesis

A statistically meaningful correlation exists between fiscal sustainability and the environmental dimension of sustainable development in Algeria and selected Arab countries during the period 2004–2022.

Sub-Hypotheses

- There is a long-term equilibrium relationship between fiscal sustainability and the environmental dimension of sustainable development in Algeria and selected Arab countries during the period 2004–2022.
- Fiscal sustainability has a statistically significant effect on the environmental dimension of sustainable development in both the short run and the long run in Algeria and selected Arab countries during the period 2004–2022.

Importance of the Study

The significance of this study stems from both its scientific and practical dimensions, as follows:

- Enriching the economic literature on the relationship between fiscal sustainability and the environmental dimension of sustainable development, particularly in Arab countries.
- Clarifying the role of fiscal sustainability in improving environmental performance and reducing pollution.
- Providing econometric evidence based on panel data models to analyze the relationship between the study variables.
- Supporting policymakers in designing fiscal policies that take environmental sustainability requirements into account.

Study Objectives:

- Analyze the impact of fiscal sustainability on the environmental dimension of sustainable development in Algeria and selected Arab countries.
- Examine the existence of a long-run equilibrium relationship between the study variables.
- Analyze the nature of the relationship in both the short run and the long run using the Panel ARDL model.
- Provide practical recommendations that contribute to strengthening fiscal sustainability and improving environmental performance in the countries under study.

Methods

- This study adopts a quantitative research methodology to analyze the impact of fiscal sustainability on the environmental dimension of sustainable development in Algeria and a selected group of Arab countries over the period 2004–2022. This approach is appropriate for the nature of the study, as it relies on annual quantitative data that can be measured and analyzed using statistical and econometric techniques. This enables the research hypotheses to be tested objectively and allows the nature, direction.
- Within this framework, the study employs a panel data methodology, which combines the time dimension with the cross-sectional dimension of the countries under investigation. This methodology makes it possible to analyze the evolution of the variables over time while accounting for differences across countries. It also takes advantage of the variation across both the time and cross-sectional dimensions, provides a larger number of observations, and allows for controlling certain unobserved country-specific characteristics. Consequently, it contributes to improving the efficiency of econometric estimates and enhancing the reliability of the empirical findings.

The Right Model for the Research Data

This study relies on time-series cross-sectional data, commonly referred to as panel data. Panel data are characterized by two main dimensions: a time dimension, represented by the number of years

covered by the study and generally denoted by T , and a cross-sectional dimension, represented by the group of countries included in the study and generally denoted by N .

The study is based on the development of an econometric model incorporating a set of carefully selected variables. Fiscal sustainability serves as the independent variable and is measured using several indicators, namely the ratio of total public debt to gross domestic product (DEGD), the ratio of the fiscal surplus or deficit to gross domestic product (SUGD), the tax gap (TAG), the ratio of oil revenues to total government revenues (OIPR), and the ratio of total government revenues to total government expenditures (PUPU).

The dependent variable captures the environmental dimension of sustainable development and is measured by per capita carbon dioxide emissions (APCO2). The study covers a sample of eight Arab countries: Iraq, Algeria, the United Arab Emirates, Saudi Arabia, Qatar, Oman, Bahrain, and Kuwait. The panel comprises $N = 8$ countries observed over the period 2004–2022, corresponding to $T = 19$ years, subject to data availability. Accordingly, the theoretical number of observations is calculated as $N \times T = 8 \times 19 = 152$ observations.

The empirical analysis initially employs static panel-data models, followed by the estimation of short-run and long-run relationships using dynamic panel-data techniques. To identify the econometric specification most appropriate for the characteristics of the sample, the analysis begins by examining the dependent variable, namely the environmental dimension of sustainable development, as proxied by per capita carbon dioxide emissions (APCO2).

In the first stage, the three basic static panel data models will be estimated:

These models will subsequently be compared using a set of appropriate statistical tests. First, the presence of individual effects among the cross-sectional units in the study sample will be examined using the Hsiao (1986) test based on the Fisher statistic. The null hypothesis assumes that the fully homogeneous model is the most appropriate specification, indicating the absence of individual effects across the cross-sectional units.

Once the appropriate specification among the static panel data models has been identified, the analysis will proceed to estimate the dynamic relationships among the study variables. This approach will enable the investigation of the nature and magnitude of these relationships in both the short run and the long run through the application of appropriate dynamic panel data models.

The econometric model is specified based on the theoretical foundations of economics and the findings of previous empirical studies, taking into account the research hypotheses and explanatory variables identified in the relevant literature. This approach aims to establish and empirically examine the functional relationship between the dependent variable and its explanatory factors. Accordingly, the present study investigates the impact of fiscal sustainability on the environmental dimension of sustainable development through an econometric analysis using panel data models for Algeria and a selected group of Arab countries over the period 2004–2022.

Hsiao (1986) Homogeneity Test

This test evaluates whether the parameters of the estimated model remain homogeneous across the cross-sectional units, based on a sample containing T time observations for N individual units. The underlying model is specified by the following linear relationship:

$$(1) \quad y_{it} = \alpha_i + \beta_i X_{it} + \varepsilon_{it}$$

- The error term ε_{it} is assumed to be independently and identically distributed, with a zero expected value and a variance of σ_i^2 . Furthermore, the model parameters α_i and β_i are allowed to vary across cross-sectional units while remaining invariant over time. Accordingly, the model specified by the preceding equation can be formulated under several alternative specifications, as presented below:
- Homogeneous intercepts α_i and identical parameter vectors β_i , such that $\alpha_i = \alpha$ and $\beta_i = \beta$ for all $i \in [1, N]$. In this case, the panel is considered homogeneous.
- Different intercepts α_i and different parameter vectors β_i across individuals. In this case, there are N different models, and the homogeneous specification is rejected.
- Identical intercepts α_i and different parameter vectors β_i across individuals, such that $\alpha_i = \alpha$ for all $i \in [1, N]$. In this case, all model parameters, except the intercepts, differ across the individual units. Consequently, N different models are obtained.
- Different intercepts α_i and identical parameter vectors β_i across the individual units, such that $\beta_i = \beta$ for all $i \in [1, N]$. In this case, the specification corresponds to an individual-effects model.

From an economic perspective, selecting the appropriate specification makes it possible to determine whether the theoretical model under investigation is homogeneous across all sample units or, conversely, whether each individual unit possesses distinct characteristics and specific features.

Table 1
Results of the hsiao (1986) homogeneity test

Hypotheses	F-Statistic	P-Value
H1	271.8179	0,00
H2	10.42321	0,00
H3	468.1020	0,00

Source. Author's elaboration based on the empirical results generated using Eviews.

The outcomes of the Hsiao (1986) homogeneity test, reported in the table, indicate that the p-value of the F1 statistic is 0.000, which is lower than the 5% significance threshold. Consequently, the null hypothesis (H_0) is rejected in favor of the alternative hypothesis (H_1), suggesting the existence of significant individual effects across the countries comprising the study sample.

The same conclusion applies to the F2 and F3 statistics, whose p-values are both equal to 0.000 and therefore statistically significant at the 5% level. Accordingly, the associated null hypotheses are rejected, providing further evidence of cross-sectional heterogeneity and confirming that the countries under investigation possess distinct individual characteristics that must be considered in the econometric estimation.

Taken together, these findings indicate that the panel units are not homogeneous and that significant individual effects are present across the countries. Therefore, the empirical analysis should account for unobserved country-specific heterogeneity. Nevertheless, the choice of the most suitable panel-data model requires further specification testing, particularly through the Hausman test, to determine the appropriate estimation framework.

Determining the Study Model

Drawing on the results of the panel data econometric analysis, the following model was specified to examine the determinants of per capita carbon dioxide emissions (APCO2):

$$APCO2 = a + \beta_1 DEGD_{i,t} + \beta_2 SUGD_{i,t} + \beta_3 TAG_{i,t} + \beta_4 OIPR_{i,t} + \beta_5 PUPU_{i,t} + \mu_i + Y_t + \varepsilon_{i,t}$$

where:

- APCO2: Per capita carbon dioxide emissions.
- DEGD: Total public debt-to-GDP ratio.
- SUGD: Fiscal surplus or deficit-to-GDP ratio.
- TAG: Tax gap.
- OIPR: Oil revenue-to-total government revenue ratio.
- PUPU: Total government revenue-to-total government expenditure ratio.
- α : Overall intercept parameter of the model.
- β_i : Coefficients of the explanatory variables.
- μ_i : Unobserved cross-sectional effects or differences
- γ_t : Unobserved time effects and differences common to the countries included in the study that vary over time.
- ε_{it} : Random error term.

The model specification appropriate to the characteristics of the sample data depends on how individual effects or unobserved heterogeneity are treated.

The above equation is estimated using the least squares method. Given the panel structure of the study data, three static panel data models can be distinguished. The first two models are estimated using the Ordinary Least Squares (OLS) method, whereas the third model is estimated using the Generalized Least Squares (GLS) method. These models are subsequently compared to determine the most appropriate model for the study data. appropriate specification for the study data (Beiling, 2023).

Table 2

Estimation of the Appropriate model for the study sample data

Per Capita Carbon Dioxide (CO ₂) Emissions (ACPO2)			
Time period: 2004–2022; N = 05; T = 34; Number of observations: N × T = 170.			
(REM)	(FEM)	Pooled Model	Explanatory Variables
-0.0009 (0.00)	0.00009 (0.13)	0.004 (0.14)	DEGD
0.01 (0.59)	0.01 (0.64)	0.21 (0,01)	SUGD
-0.004 (0.42)	-0.004 (0.44)	-0.02 (0.22)	TAG
0.07 (0.00)	0.07 (0.00)	-0.15 (0.00)	OIPR
0.04 (0.87)	0.04 (0.85)	-0.85 (0.45)	PUPU
12.01 (0.00)	11.82 (0.00)	31.13 (0.00)	C
0.15	0.95	0.07	R-squared
2.03	2.22	10.42	S.E.of regression
5.20	277.25	2.50	F-statistic
0.00	0.00	0.03	Prob (F-statistic)

Source. Author's elaboration based on the outputs of EViews 13.

*Represents the calculated statistic for the parameter estimates in the Student's t-test
Comparison between the Three Estimated Models:*

We initially determine whether or not individual effects exist within the study sample data. For this purpose, we use a *Fisher-type test*, whose null hypothesis assumes that the pooled model is appropriate, that is, there are no individual effects among the units in the studied sample. The statistic of this test is expressed as follows:

- H_0 : The pooled regression model is the appropriate model.
- H_1 : The fixed-effects or random-effects model is appropriate.

$$F_1 = \frac{(R^2_{MNC} - R^2_{MC}) / (N - 1)}{1 - R^2_{MNC} / (N \times T - n - k)}$$

Where:

- N: Represents the number of cross-sectional units (in our case, 08 countries).
- T: Represents the length of the time series considered in the study (in our case, 19 years).
- K: Represents the number of exogenous variables in the model; in our case, there are *five independent variables*.
- R^2_{FEM} : Represents the coefficient of determination under the null hypothesis. In this case, it refers to the model without individual effects, i.e., the pooled homogeneity model ($R^2_{FEM} = 0.07$).
- R^2_{PRM} : Represents the coefficient of determination of the unrestricted model under the alternative hypothesis. In this case, it refers to the fixed-effects model ($R^2_{PRM} = 0.95$).

Applying the Fisher formula gives a calculated Fisher statistic of $F_c = 333.33$, while the tabulated Fisher statistic is $F_{tab}(5, 152) = 3.04$. Accordingly, the null hypothesis is rejected at the 5% significance level (Gallo & Carfora, 2024), indicating the existence of individual effects within the sample data.

2.4 test for Determining the Type of Effects:

Hausman Test:

After conducting the Fisher test, which confirmed the existence of individual effects, the type of effects is determined using the Hausman test, o choose between the fixed-effects model and the random-effects model, the Hausman (1978) test was conducted, and the results are presented below:

Table 3
Hausman test results

Test	Chi-Square Statistic	(df)	Probability (Prob.)
Croos – section random	15.322343	5	0.0091

Source. Author's elaboration based on the outputs of EViews 13.

Based on the results obtained using EViews 13 and the Hausman test, it can be observed that the calculated Chi-square statistic ($\chi^2 = 15.32$) is greater than the tabulated statistic, which equals 11.07, at the 5% significance level. Accordingly, the null hypothesis is rejected, indicating the existence of individual effects among the explanatory variables. Therefore, the model most appropriate for the study sample data is the fixed-effects model. In addition, the high coefficient of determination supports the suitability of this model. Consequently, each cross-sectional unit has its own specific effect (Masconi & Giannini). The table below presents the fixed-effects estimates of the model for each country:

Table 4*Fixed-Effects estimates of the model for Each Country*

Country	Effect
Iraq	-14.96
Algeria	-14.78
United Arab Emirates	5.84
Saudi Arabia	-2.48
Qatar	18.75
Oman	-2.90
Bahrain	3.71
Kuwait	6.81

Source. Author's elaboration based on the outputs of EViews 13.

As shown in the previous table, there are differences in the individual fixed effects among the countries under study, with both positive and negative fixed effects being observed. Positive effects were recorded in Qatar, the United Arab Emirates, Bahrain, and Kuwait, amounting to 18.16, 5.84, 3.71, and 6.81, respectively. Negative individual effects were recorded in Iraq, Algeria, Saudi Arabia, and Oman, amounting to -14.96, -14.78, -2.48, and -2.90, respectively.

Evaluation of the Fixed-Effects Model (FEM)

After establishing, based on the results of the previous tests, that the appropriate model is the fixed-effects model, the model equation can be written as follows:

$$ACPO2 = 31.13 + 0.004DEGD_{it} + 0.21SUGD - 0.02TAG - 0.15OIPR - 0.85PUPU + e_{it}$$

Economic Evaluation

The results of estimating the fixed-effects model presented in the above equation indicate the following:

- The coefficient of the *total public debt-to-GDP ratio (DEGD)* has a positive and statistically insignificant relationship with *per capita carbon dioxide emissions (CO₂)*. A 1% increase in DEGD leads to a 0.0009% increase in per capita CO₂ emissions.
- The coefficient of the *surplus or deficit-to-GDP ratio (SUGD)* has a positive and statistically insignificant relationship with per capita CO₂ emissions. A 1% increase in SUGD leads to a 0.01% increase in per capita CO₂ emissions.
- The coefficient of the *tax gap (TAG)* has a negative and statistically insignificant relationship with per capita CO₂ emissions. A 1% increase in TAG leads to a 0.004% decrease in per capita CO₂ emissions.
- The coefficient of the *oil revenues-to-total revenues ratio (OIPR)* has a positive and statistically significant relationship with per capita CO₂ emissions. A 1% increase in OIPR leads to a 0.07% increase in per capita CO₂ emissions.
- The coefficient of the *general revenues-to-general expenditures ratio (PUPU)* has a positive and statistically insignificant relationship with per capita CO₂ emissions. A 1% increase in PUPU leads to a 0.04% increase in per capita CO₂ emissions.

Statistical Evaluation

- the coefficient of determination (R²) is equal to 95%, indicating that the explanatory variables incorporated into the model account for 95% of the variation in per capita carbon dioxide emissions (CO₂). The remaining 5% is attributable to other factors not included in the model and to the random error term.

- The Fisher (F) test confirms the overall statistical significance of the model at the 5% level. This indicates that the explanatory variables, when considered jointly, significantly contribute to explaining variations in the dependent variable, namely per capita carbon dioxide emissions (CO₂). In addition, the Student's t-test shows that certain independent variables have statistically significant effects at the 5% significance level.
- The Durbin–Watson (DW) statistic is equal to 0.31, providing evidence of serial correlation in the residuals. The presence of autocorrelation may result in inefficient or unreliable parameter estimates. Consequently, the estimated static panel-data model presents econometric limitations, supporting the use of dynamic panel-data techniques to capture both short-run and long-run relationships.

Estimation of the Dynamic Panel Model in the Short and Long Run

Stationarity of the Time Series :

Before estimating the model and investigating the existence of cointegration among the study variables, it is essential to examine the stationarity properties of the panel data. This preliminary step is necessary because the use of non-stationary series may result in spurious regression relationships and unreliable parameter estimates. Accordingly, several panel-data unit root tests are commonly employed to assess the stationarity of the variables, including (Beltagi, 2021; Ooi, 2023; Guerrouf, 2020).

Table 5

Results of the stationarity test

Test	Level / First Difference	Statistic	PUPU	OIPR	TAG	SUGD	DEGD	ACPO2
LLC (2002)	Level	Test S	1.00	-0.88	-2.43	-2.18	-1.46	-2.11
		P-value	0.84	0.18	0.00	0.01	0.07	0.01
	First Difference	Test S	-5.16	-4.86	-3.96	-7.83	-2.30	-2.20
		P-value	0.00	0.00	0.00	0.00	0.01	0.01
IPS (2003)	Level	Test S	0.05	-1.13	-1.61	-1.52	-2.28	-0.46
		P-value	0.52	0.12	0.05	0.06	0.01	0.32
	First Difference	Test S	-5.26	-4.90	-4.77	-6.55	-2.80	-3.30
		P-value	0.00	0.00	0.00	0.00	0.00	0.00
ADF-Fisher	Level	Test S	17.66	21.83	25.99	27.27	28.67	24.51
		P-value	0.34	0.14	0.05	0.03	0.02	0.07
	First Difference	Test S	55.64	52.07	50.31	66.32	33.99	41.34
		P-value	0.00	0.00	0.00	0.00	0.00	0.00
PP-Fisher	Level	Test S	25.39	40.80	44.98	37.71	66.25	17.60
		P-value	0.06	0.00	0.00	0.00	0.00	0.34
	First Difference	Test S	98.59	111.40	123.31	153.97	46.97	73.87
		P-value	0.00	0.00	0.00	0.00	0.00	0.00
Order of Integration			I(1)	I(1)	I(1)	I(1)	I(1)	I(1)

Source. Outputs of EViews 13.

The results obtained from EViews 13, particularly those of the panel unit root tests, indicate that the independent variables do not exhibit stationarity in levels. Following first differencing, however, all of these variables achieve stationarity, confirming their integration of order one, I(1). The dependent variable likewise becomes stationary after first differencing and is therefore classified as I(1). Since all variables are integrated at the same order, the presence of a long-run equilibrium relationship among them can be investigated. Accordingly, the Pedroni panel cointegration test is applied to assess the existence of such a relationship.

3.2. Panel Cointegration Relationship

Analysis proceeds to investigate the presence of a long-run cointegrating relationship among the variables through the Pedroni test. The Pedroni (1999) approach is particularly appropriate as it allows for heterogeneity across the cross-sectional units, represented by the countries included in the sample (Catalano & Forni, 2022). The test comprises two categories of statistics. The first category includes four within-dimension statistics, which assess the existence of a cointegrating relationship within the individual cross-sectional units. The second category consists of three between-dimension statistics, calculated from the average of the individual statistics across the sample units (Zairis, 2024). These statistics are used to assess the existence of a common cointegrating relationship across the countries in the sample.

Table 6
Results of the pedroni panel cointegration tests

Dimension	Estimated Model	Test Statistic	P-value
Within-Dimension	Panel V-statistic	-0.75	0.77
	Panel RHO-statistic	1.41	0.92
	Panel PP-statistic	-2.55	0.00
	Panel ADF-statistic	-2.54	0.00
Between-Dimension (Between-Group Dimension)	Group RHO-statistic	2.63	0.99
	Group PP-statistic	-2.97	0.00
	Group ADF-statistic	-2.17	0.00

Source. Author's elaboration based on the outputs of EViews 13.

The findings obtained from the Pedroni (1999) panel cointegration tests provide substantial evidence of cointegration among the variables under investigation. Specifically, the four variables under consideration.

Estimation and Analysis of the Dynamic Panel Model

After examining the order of integration of the explanatory variables and the dependent variable, namely per capita carbon dioxide emissions (ACPO2), all of which were found to be integrated of order I(1), as shown in the table presenting the order of integration, the Panel ARDL model will be estimated using the Pooled Mean Group (PMG) methodology (Chen, 2022; Limo, 2024). The optimal model among the selected specifications is the Panel ARDL (2, 0, 0, 0, 1, 0) – PMG model, selected based on the Akaike Information Criterion (AIC). Accordingly, the dynamic panel model is estimated using the Pooled Mean Group (PMG) approach to examine both the short-run and long-run relationships, in addition to the error correction term.

Table 7
Estimation results of the panel ARDL(2,0,0,0,1,0)–PMG model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DEGD	-0.045521	0.012613	-3.608980	0.0004
SUGD	0.049676	0.089377	0.555802	0.5793
TAG	0.031215	0.023523	1.326999	0.1868
OIPR	-0.061525	0.026014	-2.365050	0.0195
PUPU	-1.968288	0.929316	-2.117995	0.0361
C	25.37651	2.416432	10.50165	0.0000
Variable	Coefficient	Std. Error	t-Statistic	Prob.
COINTEQ	-0.136808	0.077237	-1.771285	0.0088
D(APCO2(-1))	0.104954	0.130892	0.801841	0.4241
D(OIPR)	0.008576	0.012801	0.669929	0.5041

Source. Author's elaboration based on the outputs of EViews 13.

Long-Run Analysis

The estimation results obtained using the *Pooled Mean Group (PMG)* approach reveal the following:

- The coefficient of the total public debt-to-GDP ratio (DEGD) has a negative and statistically insignificant relationship with per capita carbon dioxide emissions (CO₂). A 1% increase in DEGD leads to a 0.04% decrease in per capita CO₂ emissions.
- The coefficient of the surplus or deficit-to-GDP ratio (SUGD) has a negative and statistically insignificant relationship with per capita CO₂ emissions. A 1% increase in SUGD leads to a 0.04% increase in per capita CO₂ emissions.
- The coefficient of the tax gap (TAG) has a positive and statistically insignificant relationship with per capita CO₂ emissions. A 1% increase in TAG leads to a 0.03% increase in per capita CO₂ emissions.
- The surplus or deficit-to-GDP ratio (SUGD) exhibited a negative but statistically insignificant association with per capita CO₂ emissions. A 1% increase in SUGD was associated with a 0.04% rise in per capita CO₂ emissions.
- The tax gap (TAG) showed a positive yet statistically insignificant relationship with per capita CO₂ emissions. Specifically, a 1% increase in TAG was associated with a 0.03% increase in per capita CO₂ emissions.
- The oil-revenue-to-total-revenue ratio (OIPR) displayed a negative and statistically significant relationship with per capita CO₂ emissions. A 1% increase in OIPR corresponded to a 0.06% reduction in per capita CO₂ emissions.
- The ratio of general government revenues to general government expenditures (PUPU) was negatively and statistically significantly associated with per capita CO₂ emissions. A 1% increase in PUPU was linked to a 1.96% decrease in per capita CO₂ emissions.

Error Correction Term

The short-run dynamics are analyzed within an Error Correction Model (ECM), which expresses the variables in first differences while incorporating the lagged error-correction term as an explanatory variable. This specification captures the mechanism through which short-run disequilibria are gradually corrected and the system converges toward its long-run equilibrium path (Fernández-Val & Weidner, 2018).

The estimated error-correction coefficient was -0.13 , and it was negative and statistically significant at the 5% level. This result provides evidence of a stable long-run equilibrium relationship among the variables. The coefficient implies that approximately 13% of the disequilibrium generated by short-run shocks is corrected in each period, indicating a gradual adjustment of the system toward its long-run equilibrium (De Hoyos & Sarafidis, 2006).

More specifically, the coefficient suggests that approximately 13% of the disequilibrium generated by a short-run shock is corrected during each period. Thus, the system gradually adjusts and returns to its long-run equilibrium path over time.

Short-Run Analysis

The estimation results obtained using the Pooled Mean Group (PMG) approach indicate the existence of a positive and statistically insignificant relationship between the oil revenues-to-total revenues ratio (OIPR) and per capita CO₂ emissions. A 1% increase in OIPR leads to a 0.008% increase in per capita CO₂ emissions (Warhel, 2024; Kırıkkaleli & Adebayo, 2020).

Conclusion

This study investigated the impact of fiscal sustainability on the environmental dimension of sustainable development in Algeria and a selected group of Arab countries over the period 2004–

2022, employing panel-data econometric techniques. The analysis sought to examine the relationship between fiscal sustainability and environmental performance while accounting for the specific characteristics of the countries included in the sample.

The preliminary econometric tests, including tests of cross-sectional homogeneity, stationarity, and panel cointegration, confirmed the appropriateness of employing panel-data estimation techniques that account for both the cross-sectional and temporal dimensions of the dataset. Furthermore, the results of the Pedroni panel cointegration tests provided evidence of a long-run equilibrium relationship between fiscal sustainability indicators and per capita carbon dioxide emissions, thereby confirming the existence of a stable long-term relationship between fiscal sustainability and the environmental dimension of sustainable development.

The estimation results obtained using the Pooled Mean Group (PMG) approach indicated that the impact of fiscal sustainability indicators on environmental performance varies depending on the nature of the fiscal indicator considered. In the long run, the ratio of oil revenues to total revenues (OIPR) and the ratio of total revenues to total expenditures (PUPU) exhibited negative and statistically significant relationships with per capita carbon dioxide emissions. Specifically, a 1% increase in OIPR was associated with a 0.06% reduction in per capita CO₂ emissions, whereas a 1% increase in PUPU led to a 1.96% decrease in per capita CO₂ emissions. These findings suggest that more effective revenue management and improved fiscal efficiency may contribute to alleviating environmental pressures and enhancing environmental performance.

By contrast, the long-run estimates for the total public debt-to-GDP ratio (DEGD), the surplus or deficit-to-GDP ratio (SUGD), and the tax gap (TAG) were not statistically significant. This suggests that, when examined individually, these fiscal indicators do not have a statistically significant impact on per capita CO₂ emissions over the period covered by the study. Such findings may be attributed to cross-country differences in economic structures, institutional capacity, dependence on energy resources, the efficiency of public expenditure, and the implementation of environmental policies.

The estimated error-correction coefficient was negative and statistically significant, reaching -0.13 , thereby supporting the existence of a long-run equilibrium relationship among the variables under investigation. This coefficient indicates that approximately 13% of short-term deviations from the long-run equilibrium are corrected during each period, reflecting a gradual convergence of the system toward equilibrium after temporary shocks.

In the short run, the oil-revenue-to-total-revenue ratio (OIPR) exhibited a positive association with per capita CO₂ emissions; however, this relationship was not statistically significant. This result implies that the environmental consequences of fiscal sustainability may differ according to the time horizon, emphasizing the importance of distinguishing short-term adjustments from long-term equilibrium effects.

Taken together, the results suggest that the relationship between fiscal sustainability and the environmental dimension of sustainable development is multifaceted and varies across countries and over time. Fiscal sustainability should therefore be viewed beyond the conventional objectives of reducing fiscal deficits, managing public debt, and maintaining fiscal balance. It should instead be incorporated into broader environmental and development strategies through policies aimed at improving public expenditure efficiency, expanding renewable energy use, encouraging green investment, fostering environmental innovation, and ensuring the efficient allocation of public resources.

Accordingly, advancing sustainable development in Algeria and other Arab countries requires an integrated policy framework that aligns fiscal discipline with environmental objectives. This approach should prioritize improving the efficiency of public expenditure, diversifying economic structures, reducing reliance on environmentally intensive activities, and promoting cleaner and more sustainable sources of economic growth promoting renewable energy, and directing financial resources toward sustainable projects can contribute to achieving greater compatibility between fiscal sustainability and environmental protection.

Finally, the study recommends that future research incorporate additional institutional, technological, energy-related, and environmental variables and employ more advanced econometric techniques capable of capturing cross-country heterogeneity and structural differences. Such extensions would provide a deeper understanding of the mechanisms through which fiscal sustainability affects environmental performance in Algeria and the broader Arab region.

1. This section presents the main empirical findings obtained from the econometric analysis, together with the results of testing the study hypotheses. The findings of the study confirmed the validity of the two formulated hypotheses, as follows:
2. H1: There is a long-run equilibrium relationship between fiscal sustainability and the environmental dimension of sustainable development in Algeria and a selected group of Arab countries over the period 2004–2022.
3. H2: Fiscal sustainability has an impact on environmental performance, and this impact differs between the short run and the long run. Accordingly, this hypothesis was evaluated based on the statistical significance of the estimated relationships in both the short and long run.

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