International Journal of Economics and Financial Issues

ISSN: 2146-4138

available at http: www.econjournals.com

**International Journal of Economics and Financial Issues, 2025, 15(6), 402-411.**

# Environmental Taxation and Economic Growth in Africa: A Macroeconomic Panel Data Analysis

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**Received:** 18 May 2025 **Accepted:** 17 September 2025 **DOI:** https://doi.org/10.32479/ijefi.21040

**ABSTRACT**

Environmental taxation is increasingly recognized as a key tool for achieving sustainable development goals. The Rio Convention (1992), the Kyoto Protocol (1997) and the Paris Agreement (2015) demonstrate the growing global commitment to addressing climate change. These milestones underscore a growing awareness of environmental issues and have encouraged the gradual integration of ecological policies worldwide. In Africa, where environmental and economic challenges are closely interlinked, implementing tax policies that reduce negative environmental impacts while promoting economic growth is crucial. This study examines the impact of environmental taxation on economic growth in Africa and explores how economic growth can be achieved while taking environmental issues into consideration. This paper explores the relationship between environmental taxation and economic growth in Africa between 2000 and 2020 through an econometric analysis of panel data from five African countries: Morocco, Cameroon, South Africa, Niger and Tunisia. Our results show a negative and statistically significant relationship at the 5% level between environmental tax revenues and the growth rate of gross domestic product (GDP). For each one-unit increase in environmental tax revenue as a proportion of total tax revenue, the GDP growth rate decreases by 0.167 units, all else being equal.

**Keywords:** Environmental Taxation, Economic Growth, Panel Data, Africa, ARDL Model
**JEL Classifications:** H23, C3, Q5

## 1. INTRODUCTION

Growing concerns about climate change and environmental degradation have led governments to adopt specific fiscal measures aimed at promoting environmental protection. These include environmental taxation, which aims to internalize environmental costs into economic decisions. The primary objective of environmental tax policies is to reduce pollution and greenhouse gas emissions, thereby enhancing social welfare. However, these policies may also have adverse effects on economic growth, especially in the short term (Wang et al., 2015). Africa contributes <4% of global greenhouse gas emissions, with the majority originating from North and South Africa. Nonetheless, African countries face unique challenges, such as heavy dependence on natural resources, increasingly difficult access to water and deforestation (Policy Center for the New South, 2022).

According to an OECD report, environment-related tax revenues in African countries amounted to 1.1% of GDP in 2019-below the OECD's unweighted average of 2.2% for that year. Among the 30 African countries assessed, South Africa generated the highest share of environmental tax revenue; equivalent to 2.8% of its GDP (OCDE et al., 2021). The main purpose of this study is to examine the impact of environmental taxation on economic growth in Africa using an empirical panel data approach. Our central research question is as follows: What is the impact of environmental taxation on economic growth in selected African countries, and how can sustainable economic growth be achieved while addressing environmental concerns?

To investigate this relationship, we adopt an empirical panel data analysis. The data used are annual, covering 21 years, from 2000 to 2020. The panel consists of five African countries: Morocco, Cameroon, South Africa, Niger, and Tunisia. This model seks to test the following hypotheses:

- Hypothesis 1: Environmental taxation promotes economic growth by reducing $CO_2$ emissions and generating additional public revenue.
- Hypothesis 2: Environmental taxes penalize economic growth by reducing household purchasing power and increasing the tax burden.

This article is structured into three main sections. The first section reviews the relevant theoretical and empirical literature. The second section presents the methodology used for the empirical analysis, including the econometric model specification, the selected variables, and their data sources. The third section analyzes the results and provides an in-depth discussion, taking into account the economic and environmental particularities of the African continent. Finally, the article concludes with a summary of the main findings and a discussion of their policy implications for African decision-makers.

## 2. BRIEF LITERATURE REVIEW

This section presents a review of the relevant literature in two parts. First, it explores the theoretical foundations underpinning the relationship between environmental taxation and economic growth. Second, it provides an overview of empirical studies that have examined the effects of environmental taxation on economic performance across various contexts.

### 2.1. Theoretical Literature Review

The main objective of public policy is to stimulate economic growth. François Perroux, in his book Economic and Social Dictionary, defines economic growth as "a sustained increase over one or more long periods in an aggregate indicator; for a nation: Gross or net global product in real terms" (p. 115). However, this growth is often accompanied by the depletion of natural resources and a significant increase in polluting emissions. For instance, global greenhouse gas emissions reached approximately 59 billion tons of $CO_2$ equivalent in 2019, representing an increase of 12% compared to 2010 and 54% compared to 1990 (United Nations Environment Programme, 2020). To remedy these negative externalities, Pigou (1920) suggested taxing polluting activities in order to internalize their social costs. Since then, numerous theoretical studies have explored the relationship between environmental taxation and economic growth, often reaching divergent conclusions.

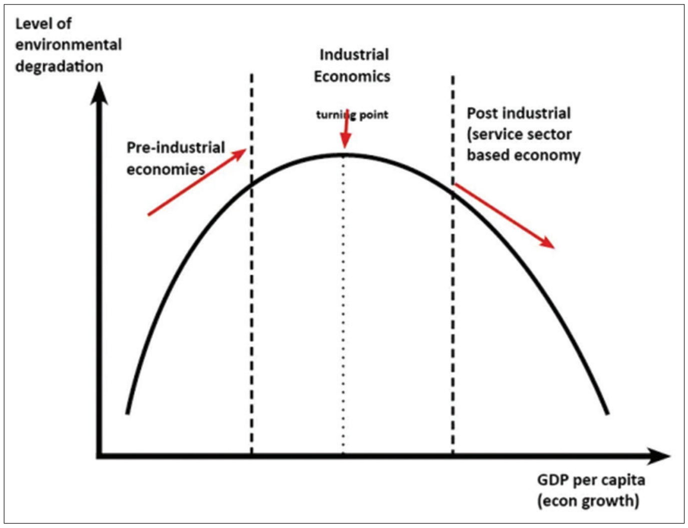
According to Bovenberg and Heijdra (1998), using an overlapping-generations model, environmental taxes can distort the return on physical capital, potentially leading to long-term reductions in capital accumulation and economic growth. As a result, future generations are likely to face a shortage of physical capital, which could lead to limited economic growth in the long term. Conversely, numerous studies suggest that environmental taxation can foster economic growth through two primary channels. Hettich (1998) and Oueslati (2002), employing a two-sector endogenous growth model, argue that high environmental taxes can enhance long-term growth by encouraging firms to invest more in pollution abatement activities. While such investments may initially reduce the resources available for production—leading to a decline in final output and, consequently, household consumption—this shift induces households to reallocate time from leisure to education. The resulting increase in human capital accumulation ultimately contributes to stronger long-term economic growth. More recently, Pautrel (2012) adds that environmental taxes can improve public health and life expectancy, which in turn reduces generational turnover and preserves intergenerational knowledge, further stimulating growth. The second channel through which environmental taxation can promote economic growth is innovation—more specifically, environmental innovation. Porter and Van Der Linde (1995) argue that strict but well-designed environmental regulations can stimulate technological innovation and competitiveness. Nakada (2004) and Hattori (2017) show that emission taxes can promote R&D in clean technologies, provided that demand for polluting goods is inelastic and that the tax burden is not overly restrictive.

The Environmental Kuznets Curve (EKC) hypothesis introduced by Grossman and Krueger (1991), posits that in the early stages of economic development, pollutant emissions remain low due to limited production activity. As industrialization advances, environmental degradation intensifies under the growing pressure of increased output. However, once a certain income threshold is reached, economic agents begin to value environmental quality more highly, leading to a preference for lifestyles that balance personal well-being with ecological preservation. The CEK hypothesis outlines three key phases through which economic growth influences the environment: the scale effect, the composition effect, and the technique effect. The scale effect indicates that increased consumption of fossil fuels drives economic growth but contributes significantly to environmental degradation, particularly in industrialized nations. As individual incomes rise, the composition effect reflects a structural shift in the economy toward less polluting industries. This transformation is supported by the technique effect, whereby higher income levels and greater awareness promote the adoption of cleaner, more efficient technologies, ultimately reducing the environmental impact of economic growth. This dynamic relationship between economic growth and environmental quality is commonly illustrated by the Environmental Kuznets Curve (EKC), as shown in Figure 1.

### 2.2. Review of Empirical Literature

The empirical literature examining the relationship between environmental taxation and economic growth is diverse and often presents contrasting results. Siriwardana et al. (2011) employed a computable general equilibrium model (CGEM) with annual data to assess the impact of a green tax on GDP in Australia. Their findings indicate that introducing a tax on carbon dioxide emissions could reduce Australia's real GDP by approximately 0.68% in the short term. Similarly, Costa-Campi et al. (2017), using on a panel data from 22 Spanish manufacturing sectors over the period 2008-2013, concluded that energy taxes have no significant effect on private-sector investment in environmental R&D.

**Figure 1:** Environmental Kuznets curve




Source: (Pettinger, 2019)

Mahmoud Hassan (2018) conducted an econometric panel data analysis on 31 OECD countries (including Australia, Austria, Belgium, Canada, and the Czech Republic) for the period 1994-2013. The study revealed that the relationship between environment tax revenues and the rate of economic growth varies if there is a mechanism for redistributing the revenues generated by these taxes. In countries where such mechanisms are present, the association between environmental tax revenues and the rate of economic growth is statistically significant and negative in both the short and long term.

Tchapchet-Tchouto et al. (2022) analyzed the effect of environmental taxes on economic growth in 31 European countries, including Austria, Belgium, Bulgaria, Croatia, Czech Republic and Denmark over the period 2009-2019. Their panel data results show a negative and statistically significant effect (at the 1% level) of environmental tax increases on GDP growth. Sensitivity analysis based on the generalized method of moments (GMM), with and without additional control variables, confirmed the robustness of these results, with significance levels ranging from 1% to 10%. Furthermore, in their study entitled "*Environmental Taxes and Economic Growth: Evidence from Panel Causality Tests*," Abdullah and Morley (2014) applied a Granger non-causality approach to panels of European and OECD countries (1995-2006). The authors identified a long-term causal relationship between GDP and net savings adjusted for environmental and/or transport taxes. While environmental tax revenues are often reinvested in ecological projects, the impact varies between countries. Notably, taxes on diesel and gasoline showed no long-term effect on output or adjusted net savings. Wealthier countries are better equipped to absorb the economic effects of environmental taxation. Nevertheless, the overall effectiveness depends on the structure of each country's environmental policy.

More recently, El Alaoui and Nekrache (2018) investigated the relationship between economic growth and environmental degradation in Morocco, Algeria, Tunisia, and Egypt in their article "*For Sustainable Economic Growth that Seeks Improving Environmental Quality: An Empirical Analysis Applied to Morocco, Algeria, Tunisia, and Egypt*." The study uses a two-stage empirical approach. In the first stage, a basic Environmental Kuznets Curve (EKC) equation is estimated for each country over the period 1970-2010 to assess the potential existence of an EKC. In the second stage, in the second stage, the model is extended by introducing additional explanatory variables such as trade openness, school enrolment rate, and urbanization rate, in order to evaluate their influence on environmental degradation and further test the EKC hypothesis. The results indicate that economic growth in these countries is often accompanied by environmental degradation, including the destruction of ecosystems and biodiversity. The relationship between economic growth and environmental damage appears complex and context-dependent, leading the authors to conclude that no single, consistent EKC pattern can be observed. Consequently, the applicability of the EKC hypothesis in these cases remains ambiguous and uncertain.

## 3. MATERIALS AND METHODS

To examine the relationship between environmental taxation and economic growth in the selected African countries, this section presents the variables employed, outlines the methodological approach based on stationarity test results, and discusses the estimation findings for the period 2000-2020.

### 3.1. Model Specification, Variables and Data Sources

#### *3.1.1. Selection of variables for the model*

The data used in this study are annual and cover a 21-year period, from 2000 to 2020. The panel includes five African Countries- Cameroon, Morocco, Niger, South Africa, and Tunisia- selected based on data availability and the desire to focus on a representative sample of African economies.

The dependent variable is the annual GDP growth rate (GDP %), which measures year-on-year changes in economic output. The independent variables include:

- Adjusted net savings as a percentage of gross national income (ENA %): This indicator is critical as it captures sustainable economic performance. Unlike gross savings, which ignore natural resource depletion and human capital degradation, adjusted net savings account for these aspects by correcting gross national income. This variable reflects not only the accumulation of physical capital but also the environmental and social sustainability of economic activities. A high ENA% indicates an economy that grows while preserving its natural capital and investing in long-term well-being—making it a key measure of intergenerational sustainability.
- Gross Fixed Capital Formation growth rate (GFCF %): Reflects investment in physical capital.
- Environmental Tax Revenue (RFE%RFT) Measured as the share of environmental tax revenue in total tax revenue this variable reflects the extent to which fiscal policy incorporates environmental considerations.
- $CO_2$ Emissions growth rate ($CO_2$%): This variable captures the environmental impact of economic activity, particularly emissions arising from fossil fuel combustion. The following Table 1 shows the variables used in the model.

**Table 1: Data description**

| Variables | Notation | Description | Source |
|---|---|---|---|
| Annual GDP growth rate | GDP% | Measures the variation in GDP over a given period, generally expressed in %. | World Bank |
| Adjusted net savings as a percentage of gross national income | ENA% | Measures sustainable economic growth by taking into account various aspects of capital. | World Bank |
| GFCF growth rate | GFCF% | Evaluates physical capital investment in an economy. | OECD |
| Green tax revenues as a percentage of total tax revenues | RFE%RFT | Evaluates the share of green tax revenues in total tax revenues. | OECD |
| Growth rate of $CO_2$ emissions | CO2% | The level of environmental pollution linked to the combustion of fossil fuels. | OECD |

Source: Author's compilation

### *3.1.2. Descriptive statistics*

The annual GDP growth rate in the selected countries averages 3.49%, with a range from −8.82% to 10.55%, reflecting both periods of economic contraction and strong expansion. $CO_2$ emissions growth rates also exhibit variability, averaging 2.25% with a peak of 8.34%. Moreover, gross fixed capital formation and adjusted net savings display relatively high standard deviations, indicating considerable variability across countries and years. This dispersion suggests differences in investment dynamics and sustainability performance within the panel. The main descriptive statistics of the panel dataset are presented in Table 2.

The following Figure 2 illustrates the evolution of GDP growth rates (GDP %) and the share of environmental tax revenues in total tax revenues (RFE%RFT) for each of the five selected countries. The data suggest that both variables exhibit broadly similar trends, with the notable exception of South Africa, where some convergence between the two indicators has been observed in recent years. A comparison of GDP growth and environmental tax revenue shares across countries reveals several insights:

- In Morocco and Tunisia, lower environmental tax shares appear to coincide with reduced economic growth in 2020, likely influenced by the COVID-19 pandemic.
- In Niger and South Africa, economic fluctuations appear less correlated with changes in environmental tax revenues, suggesting other macroeconomic factors may dominate.
- In Cameroon, the relatively low level of environmental tax revenues may explain the limited observable impact of environmental taxation on GDP growth, indicating a potentially weak implementation or influence of such fiscal policies.

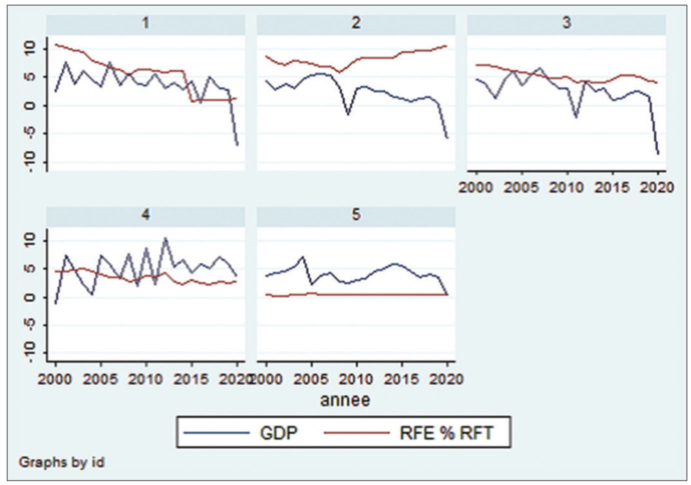
These observations provide preliminary insights into how environmental taxation may interact with economic performance across different national contexts.

**Table 2: Descriptive analysis of variables**

| Variable | Observation | Mean | Standard deviation | Min | Max |
|---|---|---|---|---|---|
| Pays | 5 | - | - | - | - |
| Id | 105 | 3 | 1.421 | 1 | 5 |
| Year | 105 | 2010 | 6.084 | 2000 | 2020 |
| GDP% | 105 | 3.490 | 2.839 | −8.818 | 10.549 |
| RFE%RFT | 105 | 4.606 | 3.122 | 0.130 | 10.760 |
| CO2% | 105 | 2.251 | 2.756 | 0.050 | 8.340 |
| GFCF% | 105 | 4.991 | 9.491 | −19.937 | 51.340 |
| ENA% | 105 | 8.016 | 10.212 | −5.857 | 27.794 |

Source: Author's compilation

**Figure 2:** Graphical representation




Source: Author's compilation (1) Morocco, (2) South Africa, (3) Tunisia, (4) Niger, (5) Cameroon

### *3.1.3. Specification test*

In panel data analysis, the first step is to determine whether the data-generating process follows a homogeneous or heterogeneous specification. To assess the presence of individual fixed effects, we conducted Fisher's test for individual (specific) effects. The hypotheses are as follows:

- $H_0$: Homogeneous specification (no individual effects)
- $H_1$: Heterogeneous specification (presence of individual effects).

The test statistics lead to the rejection of the null hypothesis, indicating the presence of significant individual effects across countries. To confirm this result and choose between a fixed effects and random effects model, we also performed the Hausman test, as shown in Table 3.

After confirming the presence of individual fixed effects through specification testing, we now proceed with the Hausman test to determine the appropriate panel data model. The Hausman test is a specification test used to determine whether the estimators from the fixed effects and random effects models are significantly different. It helps guide the choice between these two panel data estimation approaches. The hypotheses of the Hausman test are as follows:

- $H_0$: The difference between the coefficients of the fixed effects and random effects models is not systematic — the random effects estimator is consistent and efficient.

**Table 3: Specification test: Fixed-effects (within) regression**

| Variable | Coefficients | Standard errors | t | P>\|t\| | (95% confidence interval) |
|---|---|---|---|---|---|
| RFE%RFT | 0.1744457 | 0.1206491 | 1.45 | 0.151 | (−0.0650409, 0.4139322) |
| CO2% | 3.72 | 2.885911 | 1.29 | 0.200 | (−2.008489, 9.448489) |
| FBCF% | 0.1075844 | 0.0235878 | 4.56 | 0.000 | (0.060763, 0.1544057) |
| ENA% | 0.2994182 | 0.0610083 | 4.91 | 4.91 | (0.1783176, 0.4205189) |
| Constant | −0.3194717 | 0.7215576 | −0.44 | 0.659 | (−1.751752, 1.112809) |

F test that all u_i=0: F (4, 96) = 6.62 Prob>F = 0.0001
Source: Author's compilation

- $H_1$: The difference is systematic — the random effects estimator is inconsistent and biased, making the fixed effects model preferable.

In our case, the test yields a P = 0.0001, which leads to the rejection of the null hypothesis. This suggests that the random effects estimator is biased and that the fixed effects model is more appropriate for our data, as shown in Table 4.

**Table 4: Hausman test for fixed versus random effects**

| Variables | (b) fe | (B) re | (b-B) difference | sqrt (diag (V_b-V_B)) S.E. |
|---|---|---|---|---|
| RFE%RFT | 0.174 | −0.090 | 0.264 | 0.096 |
| $CO_2$% | 3.720 | 5.467 | −1.747 | - |
| FBCF% | 0.108 | 0.138 | −0.031 | - |
| ENA% | 0.299 | 0.063 | 0.237 | 0.057 |

$H_0$: Difference in coefficients not systematic $\chi^2$ (4) = (b−B)'[(Vb−VB)−1](b−B) = 26.57
Prob >$\chi^2$=0.0000
Source: Author's compilation

## 3.2. Research Hypotheses

This study aims to test the following hypotheses within the framework of our econometric model:

- Hypothesis 1: Environmental taxation stimulates economic growth by reducing $CO_2$ emissions and generating additional government revenue.
- Hypothesis 2: Environmental taxation hampers economic growth, primarily by lowering households' purchasing power and increasing the overall tax burden.
- Hypothesis 3: $CO_2$ emissions have a negative long-term impact on economic growth due to their associated external costs (e.g., public health issues and environmental degradation), despite potentially contributing positively to productivity in the short term.

## 3.3. Model Determination

Various methodological approaches have been employed in the literature to examine the relationship between environmental taxation and economic growth, including computable general equilibrium (CGE) models, panel data analysis, and standard Granger non-causality panel causality tests. However, before selecting an appropriate estimation technique, it is essential to conduct unit root tests to assess the stationarity of each time series. Additionally, cointegration tests must be carried out to determine whether a long-term equilibrium relationship exists between the dependent variable and the explanatory variables.

### *3.3.1. Unit root and stationarity tests*

A time series is considered stationary if its mean and variance remain constant over time, and its covariance depends only on the time lag between observations.

#### 3.3.1.1. Cross-sectional dependence test

Before applying unit root tests to the variables, it is essential to assess the presence of cross-sectional dependence among panel units. This step ensures the selection of appropriate stationarity tests based on the panel's structural properties. Two commonly used tests are the Breusch and Pagan Lagrange Multiplier (LM) test (1980) and Pesaran's CD test (2004). In this study, we adopt the Breusch-Pagan LM test because the time dimension (T) of our panel exceeds the cross-sectional dimension (N). The LM test is more suitable in such a case, as it is designed for panels with large T and small N. The hypotheses of the test are as follows:

- $H_0$: Cross-sectional independence (residuals are uncorrelated)
- $H_1$: Cross-sectional dependence (residuals are correlated).

The results show a P-value below the 5% threshold, leading us to reject the null hypothesis. This suggests that the panel units exhibit significant cross-sectional dependence. Consequently, second-generation panel unit root tests that account for this dependence are more appropriate for the analysis, as shown in Table 5.

#### 3.3.1.2. Results of stationarity tests: CADF by Pesaran (2003) and Breitung and Das (2005)

Among the second-generation panel unit root tests, we selected the Cross-Sectionally Augmented Dickey-Fuller (CADF) test proposed by Pesaran (2003) and the test developed by Breitung and Das (2005). These methods extend the traditional ADF framework to account for cross-sectional dependence and are widely recognized in the empirical literature.

The results of these tests are presented in the Table 6. The findings indicate that some variables—namely, the annual GDP growth rate, the $CO_2$ emissions growth rate, and the gross fixed capital formation (GFCF) growth rate—are stationary at level. This implies that these time series are stable over time and do not require differencing. The presence of a constant (C) in the test specification suggests that the series may include a constant trend component. In contrast, other variables—specifically, the share of green tax revenues in total tax revenues and adjusted net savings as a percentage of gross national income—are found to be integrated of order one. This means they become stationary only after first differencing, as shown in Table 6.

### *3.3.2. Correlation between explanatory variables*

Before selecting the appropriate econometric model to analyze the relationships among the variables, we examined the correlation

**Table 5: Hausman test results**

| Residual correlation matrix | | | | |
|---|---|---|---|---|
| 1.000 | | | | |
| 0.393 | 1.000 | | | |
| 0.365 | 0.452 | 1.000 | | |
| −0.072 | −0.029 | −0.165 | 1.000 | |
| 0.539 | 0.160 | 0.269 | 0.088 | 1.000 |

Breusch-Pagan LM test of independence: $Chi^2$ (10) = 19.330, Pr=0.0363
Source: Author's compilation

**Table 6: Stationarity test results (CADF, Breitung and Das)**

| Variables | CADF Pesaran | | Breitung and Das | | Decission |
|---|---|---|---|---|---|
| | Coefficients | P-value | Coefficients | P-value | |
| Level test | | | | | |
| GPD% | −2.358 | 0.009 | −2.347 | 0.009 | I (0) + C |
| RFE%RFT | −0.967 | 0.167 | −1.160 | 0.123 | NS |
| $CO_2$% | −4.906 | 0.000 | −4.750 | 0.000 | I (0) + C |
| GFCF% | −4.145 | 0.000 | −5.038 | 0.000 | I (0) + C |
| ENA% | 1.268 | 0.898 | −1.748 | 0.040 | NS |
| Test in first difference | | | | | |
| GPD% | — | — | — | — | — |
| RFE%RFT | −3.943 | 0.000 | −4.901 | 0.000 | I (1) + C |
| $CO_2$% | — | — | — | — | — |
| GFCF% | — | — | — | — | — |
| ENA% | −2.736 | 0.003 | — | — | I (1) + C |

Source: Author's compilation

matrix of the explanatory variables. The results presented in Table 7 show that all correlation coefficients are below 0.30, indicating weak linear relationships among the independent variables. This suggests that multicollinearity is not a concern in our model and confirms the statistical independence required for reliable regression analysis.

To further assess multicollinearity, we calculated the Variance Inflation Factors (VIF) for the independent variables. The results indicate that all VIF values are well below the commonly accepted threshold of 5, with an average of 1.07. This confirms the absence of significant multicollinearity in the model, suggesting that the regression coefficient estimates are not substantially affected by linear interdependencies among the explanatory variables, as shown in Table 8.

In fine, the series are stationary at different integration orders, I (0) and I (1), and are not auto correlated. Based on these characteristics, the appropriate estimation method for capturing both short- and long-term relationships between environmental taxation and economic growth is the autoregressive distributed lag (ARDL) panel model. This model offers several advantages: it allows for the analysis of both short-run and long-run dynamics, and it provides reliable estimates even with small sample sizes—such as the 21-year period and the five countries considered in this study. The equation of the ARDL model is written as follows:

$$\Delta GDP\%_{i,t} = \sum_{k=1}^{p-1} \lambda_{i,k} \Delta GDP\%_{i,t-k}$$
$$+\sum_{k=0}^{q-1} (\varphi_{i,1,k} \Delta CO2\%_{i,t-k} + \delta_{i,2,k} \Delta RFE\%RFT_{i,t-k}$$
$$+\delta_{i,3,k} \Delta ENA\%_{i,t-k} + \delta_{i,4,k} \Delta GFCF\%_{i,t-k})$$
$$+\varphi_i (GDP\%_{i,t-1} + \beta_{i,1} CO2\%_{i,t}$$

**Table 7: Correlation matrix of the explanatory variables**

| | RFE%RFT | $CO_2$% | GFCF% | ENA% |
|---|---|---|---|---|
| RFE%RFT | 1.000 | | | |
| $CO_2$% | −0.067 | 1.000 | | |
| GFCF% | −0.105 | 0.236 | 1.000 | |
| ENA% | 0.126 | 0.124 | 0.198 | 1.000 |

Source: Author's compilation

**Table 8: Results of the variance inflation factor (VIF) analysis**

| Variable | VIF | 1/VIF |
|---|---|---|
| GFCF% | 1.11 | 0.903 |
| ENA% | 1.07 | 0.932 |
| $CO_2$% | 1.07 | 0.935 |
| RFE%RFT | 1.04 | 0.964 |
| Mean VIF | 1.07 | |

Source: Author's compilation

Where: $\lambda_{i,k}$ and $\phi_{i,j,k}$ are the short-term coefficients; $\phi_i$ (<0) the error-correction coefficient specific to each individual; ⟦(GDP$\%_{i,t-1}$ + $\beta_{i,1}$ CO2$\%_{i,t}$ + $\beta_{i,2}$ RFE%RFT$_{i,t}$ + $\beta_{i,3}$ ENA$\%_{i,t}$ + $\beta_{i,4}$ GFCF$\%_{i,t}$) the error-correction term; $\beta_{i,1}$, $\beta_{i,2}$, $\beta_{i,3}$ and $\beta_{i,4}$ long-term coefficients.

## 3.4. Estimation of the Panel ARDL Model

### *3.4.1. Choice of the optimal lag structure for the model*

To determine the optimal lag structure for our panel ARDL model, we first identify the optimal number of lags for each individual country. The final model specification is based on the most frequently selected lag length across the countries in our panel. According to the selection criteria (such as AIC or BIC), the optimal lag order for our ARDL model is ARDL (1, 0, 0, 0, 0). This specification indicates that only the dependent variable (GDP growth) includes one lag, while the independent variables enter the model without lags, as shown in Table 9.

### *3.4.2. Cointegration test: Westerlund approach*

Westerlund (2007) proposed four cointegration tests based on the structural dynamics of the model, rather than on residual-based approaches. These tests do not require assumptions about common factors across cross-sectional units. The methodology tests the null hypothesis of no cointegration by examining whether the error correction term (ECT) in a panel error correction model is significantly different from zero.

- Group statistics (Gt and Ga): These assess whether cointegration exists in at least some of the individual panel units by testing the null hypothesis ($H_0$) of no cointegration for each cross-sectional unit.
- Panel statistics (Pt and Pa): These evaluate the presence of cointegration across the panel as a whole, with the null hypothesis ($H_0$) stating that there is no cointegration in any of the units.

The results presented in the corresponding table show that the null hypothesis of no cointegration ($H_0$) can be rejected at the 5% significance level for the variables RFE%RFT and ENA%, according to the Pt and Pa statistics. This suggests the existence of an error correction mechanism and thus confirms a long-run equilibrium relationship among the variables, as shown in Table 10.

### *3.4.3. Choice of estimation method for the ARDL model (1, 0, 0, 0, 0)*

The choice of estimation method for a panel ARDL model is crucial to obtaining reliable and interpretable results. The three most commonly used methods are the Pooled Mean Group (PMG), the Mean Group (MG), and the Dynamic Fixed Effects (DFE) estimators. According to the results, the PMG, MG, and DFE estimations yield different effects depending on the variables and models applied. The variables RFE%RFT and ENA% have statistically significant effects in both the PMG and DFE models, suggesting a strong and consistent impact on the dependent variable in these two frameworks. In contrast, CO2%, GFCF%, and ENA% show mixed results depending on the estimation method. For instance, GFCF% is significant only under the DFE model, whereas $CO_2$% shows no significant effect across any of the models.

Moreover, the lagged variables (D1) generally exhibit weak and insignificant effects, indicating that past values have limited influence on current changes in the dependent variable. Nevertheless, the MG model appears to be more sensitive to lagged changes, particularly as RFE%RFT (D1) is significant only in this specification. In summary, each estimation method (PMG, MG, and DFE) produces varying results, with certain variables displaying stronger effects depending on the approach adopted. This underscores the importance of model selection in panel ARDL estimations, as shown in Table 11.

#### 3.4.3.1. Hausman test: PMG versus DFE

The Pooled Mean Group (PMG) estimator is particularly advantageous as it allows for heterogeneity in short-term coefficients, including intercepts, the speed of adjustment toward the long-run equilibrium, and error variances across countries. However, it imposes homogeneity on long-run slope coefficients. This feature is especially suitable when we assume that countries (or a subset of them) share a common long-term equilibrium relationship, while their short-term dynamics differ. For the PMG estimator to be valid and consistent, several conditions must be met. First, there must be evidence of a long-run relationship between the variables, as indicated by a negative and statistically significant error correction term (ECT), typically >−2. Second, the residuals of the error correction model should not exhibit serial correlation, and the explanatory variables must be weakly exogenous.

In contrast, the dynamic fixed effects (DFE) estimator imposes more restrictive assumptions. It constrains both the short- and long-term coefficients, as well as error variances, to be identical across all countries, while allowing only the intercepts to vary. To determine the more appropriate model, the Hausman test is applied. Its hypotheses are:

- $H_0$: The difference in coefficients is not systematic; DFE is more efficient.
- $H_1$: The difference in coefficients is systematic; PMG is more efficient.

The test yields a P-value lower than 0.05, leading to the rejection of the null hypothesis. Therefore, the PMG estimator is preferred as the more consistent and efficient model. These results are presented in Table 12.

#### 3.4.3.2. Hausman test: PMG versus MG

The Mean Group (MG) estimator, introduced by Pesaran and Smith (1995), involves estimating separate regressions for each country and calculating the coefficients as unweighted averages of the individual country estimates. This approach imposes no restrictions on the coefficients, allowing for full heterogeneity in both the short and long term across cross-sectional units. However, for the MG approach to be statistically valid, it requires a sufficiently long time series and a substantial cross-sectional dimension — ideally 20 to 30 countries. In studies with a small number of countries (small N), the MG estimator can be sensitive to outliers and to the specification of small models (Favara, 2003).

The HAUSMAN test is used to determine whether the PMG or MG estimator is more appropriate. The hypotheses are defined as follows:

- $H_0$: There is no systematic difference between PMG and MG estimators, PMG is more efficient.
- $H_1$: There is a systematic difference between PMG and MG estimators, MG is preferred.

In our case, the P > 0.05, so we fail to reject the null hypothesis ($H_0$). This implies that there is no significant difference between the two estimators, and the PMG method is retained as the more efficient and appropriate choice for estimating the ARDL (1, 0, 0, 0, 0) model, as shown in Table 13.

**Table 9: Optimal number of lags for the ARDL model**

| Countries | GPD% | RFE%RFT | $CO_2$% | GFCF% | ENA% |
|---|---|---|---|---|---|
| Morocco | 1 | 0 | 0 | 0 | 0 |
| South Africa | 1 | 0 | 0 | 0 | 0 |
| Tunisia | 1 | 0 | 0 | 0 | 0 |
| Niger | 1 | 0 | 1 | 0 | 0 |
| Cameroon | 1 | 0 | 0 | 0 | 1 |
| More Frequent | 1 | 0 | 0 | 0 | 0 |

Source: Author's compilation

**Table 10: Results of the Westerlund cointegration test**

| Test categories | GPD%/RFE%RFT | | GPD%/CO2% | | GPD%/GFCF% | | GPD%/ENA% | |
|---|---|---|---|---|---|---|---|---|
| | Coefficients | P-value | Coefficients | P-value | Coefficients | P-value | Coefficients | P-value |
| Gt | −1.675 | 0.067 | −0.942 | 0.530 | −1.114 | 0.383 | −2.528 | 0.000 |
| Ga | −5.630 | 0.184 | −1.256 | 0.803 | −2.463 | 0.745 | −10.421 | 0.001 |
| Pt | −3.359 | 0.029 | −1.488 | 0.383 | −1.827 | 0.279 | −4.546 | 0.002 |
| Pa | −6.232 | 0.000 | −2.065 | 0.430 | −2.201 | 0.182 | −5.563 | 0.000 |

Source: Author's compilation (Gt) and (Ga) refer to Group t-test and Group alpha-test, respectively, (Pt) and (Pa) refer to Panel t-test and Panel alpha-test, respectively

**Table 11: Comparison of PMG, MG, and DFE estimation methods**

| Variable | PMG | MG | DFE |
|---|---|---|---|
| EC RFE%RFT | 0.228** | 0.242 | 0.212 |
| $CO_2$% | −3.579 | 3.570 | −1.321 |
| GFCF% | 0.0265 | 0.089* | 0.087** |
| ENA% | 0.237** | 0.058 | 0.253** |
| SR EC | −0.951** | −1.204* | −1.032** |
| RFE%RFTD1 | −1.416 | −1.029*** | −0.483 |
| CO2%D1 | 8.703* | 5.875 | 5.872* |
| FBCF%D1 | 0.066 | 0.006 | 0.011 |
| ENA%D1 | 0.163 | 0.199 | 0.040 |
| Cons | −0.269 | 3.450* | 0.083 |

Legend: *P<0.05; **P<0.01; ***P<0.001
Source: Author's compilation

**Table 12: Estimated coefficients from ARDL model (STATA 13 output)**

| Variables | (b) | (B) | (b-B) | sqrt (diag (V_b-V_B)) |
|---|---|---|---|---|
| | DFE | PMG | Difference | S.E. |
| RFE%RFT | 0.212 | 0.228 | −0.016 | 0.023 |
| $CO_2$% | −1.321 | −3.579 | 2.259 | 1.677 |
| GFCF% | 0.087 | 0.026 | 0.061 | 0.009 |
| ENA% | 0.253 | 0.237 | 0.015 | 0.023 |

$\chi2$ (4) = (b−B)′[(Vb−VB)−1](b−B) = 342.75
Prob > $\chi^2$=0.0000
Source: Author's compilation

## 4. RESULTS AND DISCUSSION

### 4.1. ARDL (1, 0, 0, 0, 0) Model Estimation Using PMG

According to the PMG estimation, there is a negative and statistically significant short-term relationship between environmental taxation and economic growth. However, in the long run, this relationship turns positive and more significant**,** suggesting potential benefits of environmental taxation over time (Table 14).

Before interpreting these results in depth, it is essential to assess the validity of the model through residual diagnostic tests.

### 4.2. Model Robustness Tests

We perform a series of diagnostic tests to assess the validity of our model. Specifically, we use the Skewness/Kurtosis test to check for normality, the Wooldridge test for autocorrelation in panel data, and the Breusch-Pagan/Cook-Weisberg test for heteroscedasticity. As shown in Table 15, the residual diagnostics reveal the presence of autocorrelation and heteroscedasticity**.** However, in STATA, there is no straightforward way to directly correct these issues within the PMG estimation framework. To address these problems, robust standard errors can be used, or alternative estimation methods may be applied.

Given that we have already confirmed the presence of fixed effects, we adopt the Feasible Generalized Least Squares (FGLS) method. This approach is suitable for correcting both autocorrelation and heteroscedasticity in panel data models and improves the reliability of our estimates.

**Table 13: Coefficient estimates obtained using STATA 13**

| Variables | (b) | (B) | (b-B) | sqrt (diag (V_b-V_B)) |
|---|---|---|---|---|
| | MG | PMG | Difference | S.E. |
| RFE%RFT | 0.2416 | 0.228 | 0.013 | 0.245 |
| CO2% | 3.570 | -3.579 | 7.150 | 6.806 |
| GFCF% | 0.089 | 0.026 | 0.063 | 0.050 |
| ENA% | 0.058 | 0.237 | -0.179 | 0.124 |

$\chi^2$ (4) = (b−B)′[(Vb−VB)−1](b−B) = 7.56
Prob > $\chi^2$=0.1092
Source: Author's compilation

**Table 14: Pooled mean group regression**

| Variables | Coefficients | Standard errors | z | P>\|z\| | (95% confidence interval) |
|---|---|---|---|---|---|
| ECM | | | | | |
| RFE%RFT | 0.228 | 0.085 | 2.680 | 0.007 | (0.066, 0.395) |
| $CO_2$% | −3.579 | 2.217 | −1.610 | 0.106 | (−7.925, 0.766) |
| FBCF% | 0.026 | 0.021 | 1.270 | 0.204 | (−0.014, 0.067) |
| ENA% | 0.237 | 0.039 | 6.080 | 0.000 | (0.161, 0.314) |
| SR | | | | | (−1.434, −0.468) |
| ECM | −0.951 | 0.246 | −3.860 | 0.000 | (−2.834, 0.002) |
| RFE%RFT (D1.) | −1.416 | 0.724 | −1.960 | 0.050 | (1.700, 15.707) |
| CO2% (D1.) | 8.703 | 3.573 | 2.440 | 0.015 | (−0.011, 0.144) |
| FBCF %(D1.) | 0.066 | 0.039 | 1.690 | 0.092 | (−0.089, 0.415) |
| ENA %(D1.) | 0.163 | 0.129 | 1.270 | 0.206 | (−2.491, 1.952) |
| Constant | −0.269 | 1.133 | −0.240 | 0.812 | (0.066, 0.395) |

Source: Author's compilation

**Table 15: Residual diagnostic tests results**

| $H_0$ test | Test applied | Statistics | Probability |
|---|---|---|---|
| No autocorrelation | Wooldridge test for autocorrelation in panel data | 282.969 | 0.0001 |
| No heteroscedasticity | Breusch-Pagan/ Cook-Weisberg test for het | 29.590 | 59 0.00 |
| Residues are normal | Skewness/Kurtosis tests for Normality | 0.0115 | 0.0204 |

Source: Author's compilation

### 4.3. FGLS Estimation

According to the results obtained, there is a negative and statistically significant relationship between environmental tax revenues (RFE%RFT) and the GDP growth rate. Specifically, a 1-unit increase in RFE%RFT is associated with a 0.167-unit decrease in GDP growth, holding other variables constant. This effect is significant at the 5% level, suggesting that environmental taxation may exert a dampening effect on economic growth. These findings are consistent with those of Siriwardana et al. (2011) and Jules-Eric et al. (2022).

Furthermore, there is a positive and statistically significant relationship between adjusted net savings (ENA %) and the GDP growth rate. A 1-unit increase in ENA% is associated with a 0.052-unit increase in GDP growth. This result, also significant at the 5% level, implies that sustainable saving behaviors contribute positively to economic performance. In contrast, $CO_2$ emissions (CO2%) do not have a statistically significant effect on GDP growth, with a P = 0.104, despite the coefficient suggesting a positive relationship (3.977).

The constant term represents the expected GDP growth rate when all explanatory variables (RFE%RFT, CO2%, FBCF%, ENA %) are equal to zero. In this hypothetical scenario, the growth rate would be 3.276%, and this constant is highly significant ($P < 0.05$), indicating a robust baseline level of economic growth within the model. These results are presented in Table 16.

This negative relationship between environmental tax revenues and economic growth can be explained by several mechanisms. First, the increase in environmental tax revenues may reduce household purchasing power, particularly for the most vulnerable populations. Second, the higher tax burden on businesses can lead to lower investment levels. Finally, reduced production may result in higher unemployment, thereby exerting downward pressure on economic growth (Ono, 2003).

It is also important to consider the specific context of the African countries analyzed in this study (Cameroon, Morocco, Niger, South Africa, and Tunisia). These countries are still at an early stage in the implementation of green taxes, compared to more advanced economies. Furthermore, the presence of numerous tax loopholes and environmentally harmful subsidies (e.g., exemptions on fossil fuel taxes in sectors such as agriculture and road transport) limits the effectiveness of environmental taxation policies (Parry et al., 2021).

Therefore, the negative impact observed in the short term could evolve into a positive relationship in the future, provided that environmental tax policies are better designed and implemented. In particular, ensuring that these taxes are earmarked for environmental purposes and that revenues are redistributed to support low-income households could enhance both environmental and economic outcomes by preserving purchasing power (Bachas et al., 2020).

Although our panel data econometric analysis (2000-2020) for the five selected African countries identifies significant links between environmental taxation and economic growth, certain methodological limitations should be acknowledged. The empirical strategy used in this study captures only direct relationships and short-term effects between variables. It does not account for the broader general equilibrium effects that environmental taxation may generate across the entire economy. According to Dixon and Jorgenson (2013), traditional econometric approaches often limit themselves to analyzing direct relationships and short-term effects between variables, without accounting for the complex interactions and feedback effects that characterize the entire economic system.

A more comprehensive analytical framework, such as a Computable General Equilibrium Model (CGE), would offer deeper insights. CGE models allow for the simulation of indirect and long-term effects by incorporating interactions between economic agents and sectors, including redistribution effects among consumers and producers Hertel (1997). Employing such a model in future research would provide a more robust understanding of how environmental taxation can support sustainable economic development, particularly in the context of the ecological transition.

**Table 16: FGLS estimation results for the panel data model**

| Variables | Coefficients | Standard errors | z | P>\|z | (95% confidence interval) |
|---|---|---|---|---|---|
| RFE%RFT | −0.167 | 0.066 | −2.55 | 0.011 | (−0.296, −0.039) |
| $CO_2$% | 3.977 | 2.446 | 1.630 | 0.104 | (−0.818, 8.772) |
| GFCF% | 0.125 | 0.022 | 5.770 | 0.000 | (0.083, 0.168) |
| ENA% | 0.052 | 0.023 | 2.310 | 0.021 | (0.008, 0.097) |
| Constant | 3.276 | 0.427 | 7.670 | 0.000 | (2.439, 4.113) |

Source: Author's compilation

Computable General Equilibrium (CGE) models are particularly well suited for long-term projections of meso- and macroeconomic policies, as well as for evaluating redistributive effects. Their flexibility and parameterization method, often based on calibration, require fewer data than econometric estimations. Consequently, these models are better adapted to the statistical structure of developing countries (Tamsamani, 2014).

## 5. CONCLUSION

This study investigated the impact of environmental taxation on economic growth in five African countries—Morocco, Cameroon, South Africa, Niger, and Tunisia—over the period 2000-2020 using a panel data econometric model. Our findings reveal a statistically significant negative relationship between environmental tax revenues and GDP growth, suggesting that in the short term, environmental taxation may hinder economic expansion, particularly when tax burdens affect household purchasing power and business investment. This outcome aligns with the conclusions of Ono (2003), who emphasized that poorly designed green taxes can exacerbate economic vulnerabilities if not accompanied by appropriate redistributive measures. However, the analysis also highlighted a positive relationship between adjusted net savings (which accounts for investment in education and the depletion of natural resources) and GDP growth, underlining the potential for environmentally responsible fiscal policies to contribute to sustainable development in the long run. As supported by the World Bank (2020), "revenue recycling mechanisms that redistribute environmental tax revenues to low-income households can mitigate negative distributional effects and support social equity."

The methodological framework used in this study—based on traditional econometric modeling—focuses primarily on direct and short-term effects. As Dixon and Jorgenson (2013) point out, such approaches often overlook the complex intersectoral and feedback effects within the economy. To overcome these limitations, future research could employ Computable General Equilibrium (CGE) models, which provide a more robust framework for capturing the indirect and long-term impacts of environmental taxation (Hertel, 1997). These models are particularly well suited to developing economies, as they require fewer data inputs than econometric estimation and can accommodate the structural specificities of African economies (Tamsamani, 2014).

In light of our findings, environmental tax policies in Africa must be better designed and targeted. As the OECD (2019) emphasizes, "when properly designed and targeted, environmental taxes can drive sustainable growth by incentivizing cleaner production while protecting vulnerable populations through revenue recycling." Policymakers should ensure that revenues from green taxes are transparently allocated to environmental protection and social support mechanisms to maintain economic stability and enhance public acceptability. Ultimately, while environmental taxation currently appears to constrain economic growth in the selected countries, it holds the potential to become a key driver of sustainable development—provided that its design incorporates long-term economic interactions, equity considerations, and clear environmental objectives.

## 6. ACKNOWLEDGMENTS

The authors wish to express their sincere gratitude to the Moroccan CNRST for the support provided under the « PhD - Associate Scholarship - PASS program », which made this research possible.

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