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Decoupling economic growth from climate change: Morocco's position within the MENA Region

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ABSTRACT

The aim of this article is to examine whether economies can achieve sustainable economic growth without compromising the environment, and to assess Morocco's position within the MENA Region. The study focuses on a panel of 16 countries from the region, using CO_2 emissions and gross domestic product (GDP) over the period 1990-2023. The logarithmic series are decomposed into trend and cyclical components using the Hodrick-Prescott filter, and robust econometric methods are applied to estimate the Kuznets trend elasticity, notably fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS). The empirical results show that countries in the panel experience a moderate relative decoupling between economic growth and CO_2 emissions, meaning that emissions increase at a slower rate than GDP. Morocco ranks seventh in the panel, indicating relatively favorable environmental performance compared to several high-emission countries. However, this level of decoupling remains insufficient to trigger a path of absolute emissions reduction.

Keywords: decoupling, FMOLS, DOLS, carbon, emissions, climate change, GDP

INTRODUCTION

Climate change remains a critical issue that attracts the attention of national and international organizations, as it poses a major challenge for the entire world across environmental, economic, and social dimensions (Stern, 2007). According to the Intergovernmental Panel on Climate Change (2023), anthropogenic activities are responsible for a 1.09 °C increase in the global average temperature relative to the pre-industrial period (1850-1900). This increase has exceeded the pace observed over any other fifty-year period since 1970.

Estimates of the global average temperature suggest that in the medium term by the 2030 horizon, the critical threshold of 1.5 °C could be exceeded with a probability of about 50%, reflecting an alarming situation and highlighting the need to implement international climate commitments (Intergovernmental Panel on Climate Change, 2021; United Nations Framework Convention on Climate Change, 2022). In this regard, the trajectories proposed by the nationally determined contributions (NDC) will be largely exceeded by global greenhouse gas (GHG) emissions in 2030 (58 $GtCO_2$) (UNEP, 2023). In this context, the remaining carbon budget is sharply reduced, standing at about 500 $GtCO_2$ for a 50% probability of not exceeding the 1.5 °C threshold, and at 1.150 $GtCO_2$ for a 67% probability of limiting warming to 2 °C (Intergovernmental Panel on Climate Change, 2021).

From this perspective, GHG emissions not only affect the environment but also lead to economic losses and increase social vulnerabilities, thereby compromising the achievement of sustainable development, particularly in the least developed countries (Stern, 2007).

In the literature, the relationship between economic growth and environmental degradation constitutes a central issue (Dinda, 2004; Stern, 2004). It is mainly framed within the environmental Kuznets curve (EKC) hypothesis, which posits that a country's economic development is accompanied by environmental deterioration in the early stages of growth, before this degradation decreases once a certain income threshold is reached (Grossman & Krueger, 1995; Panayotou, 1993). Graphically, this relationship takes the form of an inverted U or a bell-shaped curve, linking indicators of economic development to those of environmental degradation.

For information, the term EKC was initially introduced by Kuznets in another context, namely the relationship between

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income inequality and income per capita (Kuznets, 1955). This same relationship was applied in the environmental context by Panayotou (1993) and also by Grossman and Krueger (1991). However, the literature on the relationship between economic growth and climate change, as described by the EKC, presents limitations. Indeed, the majority of studies examining the EKC hypothesis present several methodological limitations that may nuance the conclusions. Among these limitations are the absence of stationarity and cointegration tests of the variables (Engle & Granger, 1987; Phillips & Hansen, 1990), the choice of restricted study periods, the neglect of short and long-term dynamics (Pesaran et al., 1999), and the non-respect of the intra-country separation hypothesis, which suggests conducting country-by-country analyses to accurately capture the dynamics specific to each economy, rather than estimating the relationship at the panel level, which may simply reflect the aggregation of highly disparate national trajectories (Dinda, 2004; Stern, 2004).

It is within this context that the present article is situated, aiming to enrich the existing debate by focusing on the relationship between gross domestic product (GDP) and CO_2 emissions in the MENA Region. While previous studies have largely examined the EKC hypothesis using aggregated or country-specific data, they often neglect short- and long-term dynamics, stationarity and cointegration issues, and the decomposition of emissions and growth into trend and cyclical components. To address these gaps, our study uses a panel of 16 MENA countries over the period 1990-2023, applying the Hodrick-Prescott (HP) filter to separate trend and cyclical components, and employing robust econometric methods notably, fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS), that account for heterogeneous panel data, non-stationarity, and cointegration. This approach allows us to provide new insights into the decoupling of economic growth and GHG emissions, quantify trend elasticity more accurately, and capture both short- and long-term dynamics across the region, thus advancing the current state of knowledge on climate-growth interactions.

Our article addresses the issue of decoupling between emissions and growth by decomposing the initial series of the variables into trend and cyclical components, using the HP filter (Hodrick & Prescott, 1997) and mobilizing advanced and robust econometric methods that go beyond classical methods which do not consider the violation of ordinary assumptions, notably FMOLS and DOLS (Phillips & Hansen, 1990; Stock & Watson, 1993). These methods are applied to estimate trend elasticity, are adapted to heterogeneous panel data on both income and emissions, allow correcting biases related to non-stationarity and cointegration, and capture short-term effects and long-term dynamics.

The remainder of the article is organized into six sections:

(1) a literature review highlighting the diversity of studies on the theme of decoupling,

(2) an analysis of the climate situation of the MENA Region exploring the historical evolution of emissions between 1990 and 2023 (Our World in Data and World Bank),

(3) a detailed methodological framework presenting the HP filter technique for decomposing series into trend and cyclical components, panel stationarity tests and Pedroni (1999) panel cointegration tests, and econometric estimation methods, notably FMOLS and DOLS,

(4) a section devoted to the presentation and interpretation of the results,

(5) a section on policy implications for Morocco and the MENA Region, and

(6) a conclusion summarizing the main information and results of this paper.

LITERATURE REVIEW

The economic debate has shown strong interest in the link between economic growth and climate change, as the latter poses a major and persistent challenge on a global scale. Several studies have highlighted the historical presence of a positive, exponential relationship between economic growth and GHG emissions, driven by industrial activities that rely on high energy consumption from fossil fuels. However, the results of these works depend on several criteria, notably the choice of the periods studied and the panel of countries, the independent variables selected, and the econometric methods used to examine the relationship between GDP and CO_2 emissions.

The foundation of these studies is based on the works of Grossman and Krueger (1995), as well as Panayotou (1993), who suggested the existence of a relationship between economic development and environmental degradation in the form of an inverted U. This relationship is now known as the EKC, inspired by the famous Kuznets curve that addresses the link between income inequality and income per capita. According to the Kuznets principle, during the early phases of economic development, GHG emissions increase before decreasing once a certain level of development is reached, accompanied by improvements in environmental conditions.

Subsequently, several studies have attempted to empirically demonstrate the validity of this relationship for a number of country groups, over various periods, for several types of GHG. However, the results remain insufficient and less convincing. Indeed, Destek et al. (2020) confirmed the validity of this hypothesis only for France, Italy, and the United States, within a panel of G7 countries, and for periods prior to 1973. Similarly, Shahbaz and Sinha (2019), after a detailed review of the literature covering the period 1991-2017, conclude that the results on the EKC applied for CO_2 emissions are indeed insufficient. The authors call for integrating energy and social components into future studies and for unifying the econometric methods used and the explanatory variables employed.

At the same time, some studies argue that economies follow different economic and environmental trajectories, which makes generalization difficult. Indeed, using meta-analytic methods, Sarkodie and Strezov (2019) demonstrate substantial heterogeneity in the EKC across levels of GDP per capita, arising from the adoption of diverse methodological approaches.

Within this perspective, Narayan and Narayan (2010) suggested comparing the short- and long-term elasticities of emissions with respect to GDP. The results show that if the long-term elasticity is lower than the short-term elasticity, then emission reductions can be achieved through income growth. Al-Mulali et al. (2016) used this approach for Kenya to address multicollinearity problems; however, this method does not allow for a complete analysis of the decoupling phenomenon nor for tracing the evolution of the relationship between GDP and emissions.

Moreover, several studies have concluded that, to improve environmental conditions, countries must support structural changes (green energy transition, green fiscal incentives, etc.), which constitute a strategic lever for reducing GHG emissions (Panayotou, 2000). However, Padilla (2017) confirmed that in the absence of public policies oriented towards environmental protection, less developed countries experience periods of increased environmental degradation during phases of economic growth.

Pao and Tsai (2010) showed that, for the BRIC countries over the period 1971-2005, long-term elasticities are highly heterogeneous and statistically significant, with positive values for India and China and negative values for Russia. Furthermore, Heutel (2012), Doda (2014), and Sheldon (2017) show that cyclical CO_2 emissions are more volatile than GDP and decline more rapidly during economic downturns. York (2012), for his part, confirms that during periods of economic growth, emissions tend to increase rapidly.

Cohen et al. (2018) proposed an approach similar to that used in our article, decomposing the series into levels, trend components, and cyclical components of GDP and CO_2 emissions for the 20 largest GHG-emitting countries over the period 1990-2014. They concluded that trend elasticities of CO_2 emissions decrease over time with income, reflecting the ability of large economies to effectively decouple income from emissions.

Quaye et al. (2025) expanded the scope of analysis to include consumption-based emissions and argued that, thanks to technological development and countries' willingness to create a healthy environment, some have managed to decouple GDP per capita from consumption-based CO_2 emissions. Using a latent variable model, they confirmed significant, decreasing relationship between GDP and emissions, highlighting the important role of economies in shaping their public policies. Huang (2024) confirms this same idea and describes that governments play a major role in designing decoupling strategies that combine economic development and environmental preservation.

Xu (2025) argued that the Chinese province of Jiangxi, over the period 2010-2022, exhibits weak decoupling, characterized by relatively low carbon intensity but increasing emissions.

Warsame et al. (2025) confirmed the presence of an EKC for emissions in IGAD countries, arguing that, in the long run, renewable energy and population growth play an important role in mitigating environmental degradation. Similarly, Menegaki et al. (2025) show that transitioning to green energy is necessary to reduce emissions from tourism and urbanization in emerging E7 economies.

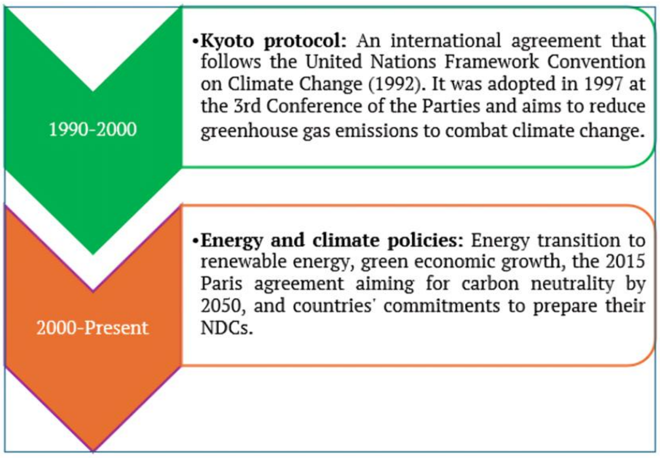

Figure 1. Timeline of the global economy in relation to energy and the environment (Source: Authors' own elaboration)

Overall, the literature shows that methodologies differ; however, achieving absolute decoupling remains difficult unless governments effectively orient their public policies toward green, inclusive, and sustainable models.

ANALYSIS OF THE CLIMATE SITUATION OF COUNTRIES IN THE MENA REGION

The global economy has historically been marked by energy and environmental events (**Figure 1**). Two main phases characterize the contemporary economy: the Kyoto protocol, which is an international agreement following the United Nations Framework Convention on Climate Change (1992). Adopted in 1997 at the 3rd Conference of the Parties, this protocol aims to reduce GHG emissions to combat climate change. It sets emission reduction targets for developed countries and establishes mechanisms such as the carbon market to promote the implementation of mitigation measures and the development of the first technological policies in the energy sector. Thus, we propose to study the income elasticities of CO_2 emissions for each country over the period 1990-2023, to examine their evolution and assess the environmental impact of these phenomena. The current climate situation in the MENA Region is highly alarming due to emissions generated by oil-producing countries. The increase in these emissions is driving dangerous weather phenomena, which require urgent and concrete climate action.

This section will explore the latest available figures for the study period and present an analysis of countries' positions, from the least to the most emitting. **Figure 2** presents a comparison of countries' emissions in 1990 and 2023.

The majority of the 16 countries in the MENA Region experienced rapid industrialization, fossil-fuel-based energy consumption, and urbanization, accompanied by an acceleration in emissions. The analysis of the chart shows remarkable heterogeneity among the countries in the panel. Some Middle Eastern countries recorded considerable increases between 1990 and 2023, notably Saudi Arabia (+264%), the United Arab Emirates (UAE) (+260%), Oman (+325%), and Qatar (+771%), reflecting their dependence on fossil fuels and rapid domestic demand growth.

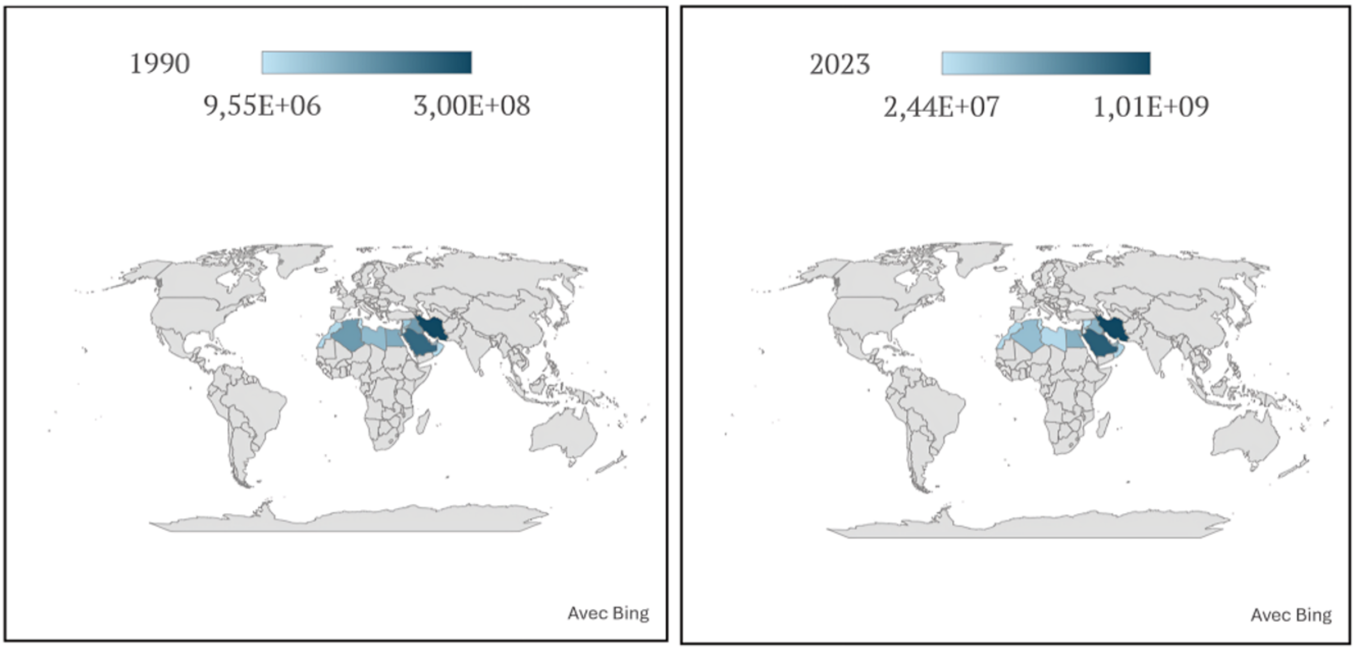

Figure 2. Evolution of CO_2 emissions (tons) of the 16 countries in the MENA Region in 1990 and 2023 (Source: Our World in Data)

Thus, some North African countries experienced more moderate growth, such as Morocco, which increased from 3.43E+07 in 1990 to 9.58E+07 in 2023, representing a 179 % increase. By contrast, due to economic and institutional disruptions, Syria recorded a 48% decrease.

In 2023, Morocco ranks seventh, placing it in the lower half of this panel. This position reflects Morocco's ambition to honor its international commitments in terms of climate and sustainable development.

METHODOLOGICAL APPROACH

The objective of this paper is to estimate the elasticity of CO_2 emissions with respect to GDP in 16 economies of the MENA Region over the period 1990-2023.

Empirically, the relationship between GDP and CO_2 emissions is expressed through the following specification:

$$\Delta CO_{2_{it}} = \alpha + \omega \Delta GDP_{it} + u_{it}, \quad (1)$$

where that $\Delta CO_{2_{it}}$ et ΔGDP_{it} denotes CO_2 emissions and GDP of country i at time t, respectively.

However, this equation may lead to misleading results when estimating the elasticity ω, since it does not account for the distinction between trend and cyclical components.

To address this issue, we adopt the methodological approach proposed by Cohen et al. (2018), which is based on decomposing the series of GDP and CO_2 emissions into their trend and cyclical components using the HP filter, which consists in minimizing the following function:

$$\min_{\tau_t}\{\sum_{t=1}^{T}(x_{i_t} - x_{i_t}^{T})^2 + \lambda \sum_{t=1}^{T}[(x_{i_t}^{\tau} - x_{i_{t-1}}^{\tau}) - (x_{i_{t-1}}^{\tau} - x_{i_{t-2}}^{\tau})]\}, \quad (2)$$

where x_{i_t}= {GDP_{i_t} , $CO_{2_{i_t}}$} and the smoothing parameter λ is set at 100, as is common practice when using annual data.

According to Cohen et al. (2018), the relationship between cyclical GDP and cyclical CO_2 emissions is given by the environmental Okun's (1962) law:

$$logCO_{2_{it}}^{c} = \alpha^{c} logGDP_{it}^{c} + \varepsilon_{it}^{c}, \quad (3)$$

where $CO_{2_{it}}^{c}$ and Y_{it}^{c} are the cyclical components of the logarithm of CO_2 emissions and the logarithm of GDP, respectively, and α^{c} is the cyclical Okun's (1962) elasticity.

Similarly, the long-term trend relationship between CO_2 emissions and GDP is given as follows:

$$logCO_{2_{it}}^{\tau} = \alpha_{it} + \alpha^{\tau} logGDP_{it}^{\tau} + \varepsilon_{it}^{\tau}, \quad (4)$$

where a constant α_{it} is included in this model's estimation to capture initial differences between countries and the historical level of emissions.

The trend elasticity, or Kuznets estimator α^{τ}, which links the trend component of the logarithm of GDP ($logGDP_{it}^{\tau}$) to the trend component of the logarithm of CO_2 emissions ($logCO_{2_{it}}^{\tau}$), is the object and main focus of this paper.

To estimate this elasticity, we use advanced econometric models that go beyond the classical methods commonly used in the literature and do rely on ordinary assumptions, namely FMOLS and DOLS. FMOLS is a method that aims to correct endogeneity and autocorrelation problems in cointegration models by applying a semi-parametric correction to long-run residuals. In turn, DOLS explicitly includes lags of the independent variable in the regression to correct for endogeneity and account for short-term dynamics.

Indeed, FMOLS and DOLS estimations provide results that are robust relative to classical OLS estimation for data that satisfy the underlying assumptions. However, when assumptions are violated, these estimators yield more reliable

Table 1. Country-level descriptive statistics of CO_2 and GDP variables (Our World in Data & World Databank)

Country	Variable 1: CO_2 (in tons)				Variable 2: GDP (in constant 2011 international dollars, PPP)			
	Minimum	Maximum	Mean	Standard error	Minimum	Maximum	Mean	Standard error
Algeria	1.47E+08	2.77E+08	2.03E+08	4.05E+07	2.90E+11	6.99E+11	4.72E+11	1.39E+11
Bahrein	2.67E+07	6.70E+07	4.78E+07	1.22E+07	2.15E+10	9.02E+10	5.39E+10	2.18E+10
Egypt	1.14E+08	3.47E+08	2.34E+08	7.50E+07	4.68E+11	1.91E+12	1.03E+12	4.34E+11
Iran	3.00E+08	1.01E+09	6.54E+08	2.24E+08	5.28E+11	1.44E+12	9.61E+11	2.77E+11
Iraq	6.58E+07	3.59E+08	2.02E+08	8.55E+07	6.79E+10	6.14E+11	3.45E+11	1.70E+11
Jordan	1.20E+07	3.22E+07	2.32E+07	6.37E+06	2.75E+10	1.07E+11	6.62E+10	2.64E+10
Kuwait	4.72E+07	4.99E+08	1.20E+08	7.23E+07	3.85E+10	2.34E+11	1.64E+11	5.78E+10
Lebanon	9.55E+06	3.26E+07	2.13E+07	6.38E+06	1.92E+10	9.94E+10	6.53E+10	2.27E+10
Libya	5.05E+07	1.07E+08	8.97E+07	1.11E+07	6.81E+10	1.37E+11	9.88E+10	1.94E+10
Morocco	3.43E+07	9.64E+07	6.51E+07	1.99E+07	1.09E+11	3.39E+11	2.12E+11	7.69E+10
Oman	2.85E+07	1.21E+08	7.24E+07	3.00E+07	6.21E+10	1.93E+11	1.23E+11	4.07E+10
Qatar	2.33E+07	2.03E+08	1.15E+08	5.88E+07	3.09E+10	3.09E+11	1.56E+11	1.11E+11
Saudi Arabia	2.39E+08	8.71E+08	5.50E+08	1.96E+08	6.39E+11	1.85E+12	1.16E+12	3.95E+11
Syria	3.24E+07	8.83E+07	6.46E+07	2.04E+07	7.33E+10	2.21E+11	1.29E+11	3.99E+10
Tunisia	1.94E+07	4.16E+07	3.19E+07	7.08E+06	5.58E+10	1.56E+11	1.12E+11	3.40E+10
UAE	7.83E+07	2.82E+08	1.85E+08	7.29E+07	2.05E+11	7.18E+11	4.39E+11	1.63E+11

estimates and more precise confidence intervals. Thus, this trend elasticity is given by as follows:

$$\alpha_{it}^{\tau} = \frac{\delta logCO_{2_{it}}}{\delta logGDP_{it}} - constant_{it}, \quad (5)$$

where $constant_{it} = \frac{\alpha_{i_t}}{logGDP_{i_t}}$.

This Kuznets curve shows that as countries' GDP increases, their CO_2 emissions also increase, indicating a positive income elasticity. If this elasticity is positive and less than 1, it implies that emissions increase less rapidly than GDP, indicating relative decoupling. If this elasticity is negative, then the country exhibits absolute decoupling, implying that as GDP increases, CO_2 emissions decrease. However, if this elasticity exceeds unity, it is concluded that the country is deemed not to exhibit decoupling. This implies the following cases:

Absolute decoupling:

$$\frac{\delta logCO_{2_{it}}}{\delta logGDP_{it}} - constant_{it} = \frac{\delta CO_{2_{it}}}{\delta GDP_{it}} \frac{GDP_{it}}{CO_{2_{it}}} - constant_{it} < 0. \quad (6)$$

Relative decoupling:

$$0 < \frac{\delta logCO_{2_{it}}}{\delta logGDP_{it}} - constant_{it} = \frac{\delta CO_{2_{it}}}{\delta GDP_{it}} \frac{GDP_{it}}{CO_{2_{it}}} - constant_{it} < 1. \quad (7)$$

No decoupling:

$$\frac{\delta logCO_{2_{it}}}{\delta logGDP_{it}} - constant_{it} = \frac{\delta CO_{2_{it}}}{\delta GDP_{it}} \frac{GDP_{it}}{CO_{2_{it}}} - constant_{it} > 1. \quad (8)$$

RESULTS AND DISCUSSION

Descriptive Statistics

Table 1 presents the main descriptive statistics of the variables studied over the period 1990-2023.

The variables for CO_2 emissions (in tons) and GDP (in constant 2011 international dollars, PPP) are sourced from Our World in Data and the World Bank, respectively, and cover the period from 1990 to 2023.

The descriptive statistics highlight strong inter-country heterogeneity in both CO_2 emissions and GDP within the MENA panel. They reveal a potential structural correlation between economic size and emission levels, particularly pronounced for large energy-based economies (Iran, Saudi Arabia, and the UAE). Average CO_2 emissions vary considerably across countries, reflecting highly differentiated energy and industrial profiles. Indeed, the highest average levels are observed in Iran and Saudi Arabia, reflecting the significant weight of these economies in hydrocarbon production. However, the wide gap observed at comparable GDP levels indicates significant differences in carbon intensity, warranting an in-depth econometric analysis of the growth-emissions relationship.

Thus, we propose exploring the boxplots of CO_2 emissions and GDP below to provide a deeper understanding of the descriptive statistics for all countries in the panel (**Figure 3**).

The distribution of CO_2 emissions and GDP highlights profound structural heterogeneity among the countries of the MENA panel, both in terms of growth trajectories and environmental profiles.

Each boxplot in **Figure 3** summarizes the statistical distribution of the variables over the period 1990-2023. Specifically, the central line within each box represents the median value, indicating the typical level of emissions or GDP for a given country. The lower and upper bounds of the box correspond to the first quartile (Q1) and third quartile (Q3), capturing the interquartile range (IQR) and thus the dispersion of the middle 50% of observations. The "whiskers" extend to the minimum and maximum values within 1.5 times the IQR, reflecting the range of typical variation, while points beyond the whiskers represent outliers, indicating extreme observations or unusual shocks over the study period.

Large energy-based economies, particularly Iran, Saudi Arabia, and the UAE, are simultaneously characterized by high GDP levels and median CO_2 emissions well above those of other countries, with substantial year-to-year variation, as reflected in wider boxes and longer whiskers. Morocco, for its

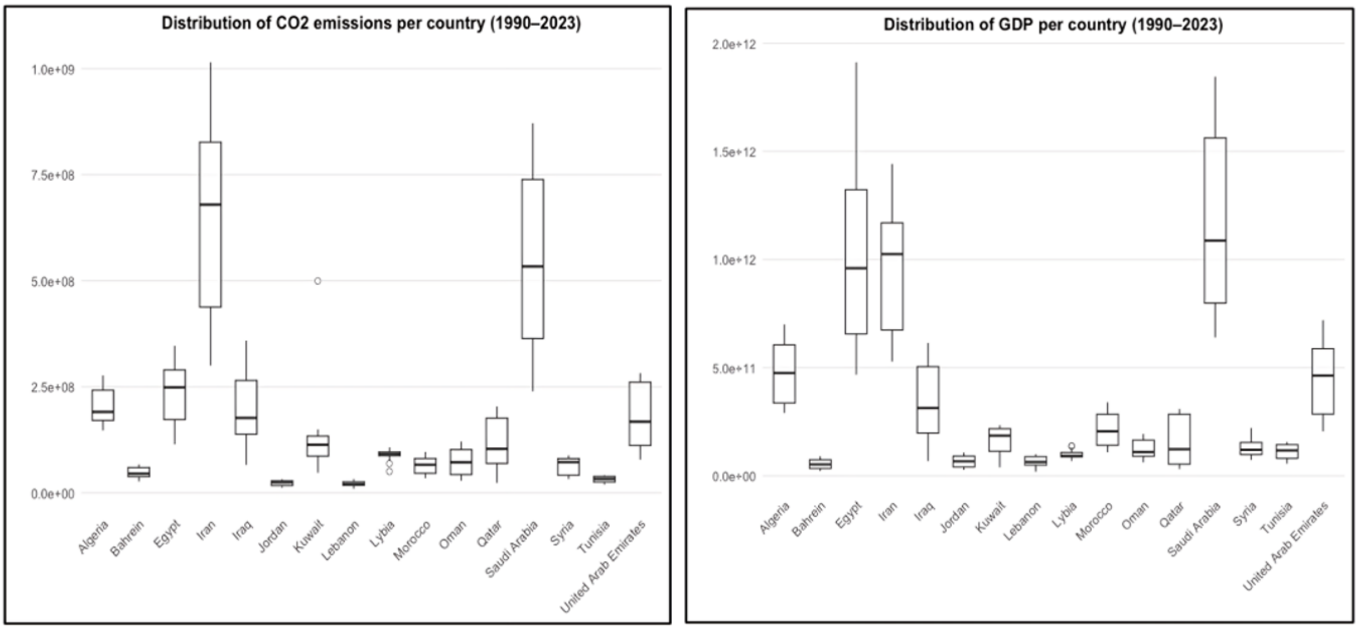

Figure 3. Boxplot of the distribution of CO_2 emissions (tons) and GDP (in constant 2011 international dollars, PPP) by country, 1990-2023 (Source: Authors' own elaboration)

Table 2. Stationarity test

Panel stationarity test: Im-Pesaran-Shin test					
Variable	**Wtbar**	**p**	**Wtbar after differencing**	**p after differencing**	**Interpretation**
logCO_2	0.52	0.70	-4.82	6.89e-07	The variable in the panel is stationary after first differencing.
logGDP	4.66	1.00	-6.60	1.97e-11	The variable in the panel is stationary after first differencing.

part, occupies an intermediate position, accompanied by a gradual increase in GDP and a controlled rise in emissions, reflecting a transition trajectory in which economic growth occurs with a more contained carbon intensity than in major oil-based economies.

This preliminary analysis justifies the use of FMOLS and DOLS econometric methods to estimate trend elasticities and rigorously analyze the environmental component of economic development in the region.

Decomposition of the Series Using the HP Filter

As mentioned previously, it is relevant to decompose the level series into its trend and cyclical components using the HP filter. Below are some examples of the decomposition of the logarithm of CO_2 emissions andthe logarithm of GDP (**Appendix A**).

In the examples presented, the left-hand graph shows the cyclical component of the logarithm of CO_2 emissions and the logarithm of GDP, while the right-hand graph presents the trend component of the same variables. It is observed that, for all countries, the cyclical component of emissions follows the same trajectory as GDP. Similarly, for the trend component, it is noted that as countries generate wealth, they tend to emit CO_2 at different levels.

Stationarity Test

The Im-Pesaran-Shin panel stationarity test examines the time-series properties, by country and across the panel, of the trend components of the logarithms of CO_2 emissions and GDP (**Table 2**). Moreover, the cyclical component is stationary by construction.

Following the Im-Pesaran-Shin panel unit root test, we conclude that the trend series of the logarithm of GDP and CO_2 emissions in the panel are stationary only after first differencing.

Table 3. Panel cointegration test of Pedroni (1999)

	Empirical statistics	Standardized statistics
Panel tests		
nipanel	1.00	-4.41
rhopanel	-105.63	-8.53
tpanelnonpar	-31.36	-17.36
tpanelpar	-2,214.09	-1,765.49
Group tests		
rhogrpoup	-107.71	-7.73
tgroupnonpar	-32.52	-25.95
tgrouppar	-30.56	-23.52

Panel Cointegration Test

Pedroni (1999) panel cointegration test is applied to demonstrate the existence of a long run cointegration relationship between the logarithms of CO_2 and GDP for the trend series of the panel of countries studied. The results of this test are presented below (**Table 3**).

The results show that both panel and group statistics are strongly negative and statistically significant at the 1% and 5% levels. These results lead to the rejection of the null hypothesis of no cointegration and confirm the existence of a long-run relationship between economic growth and CO_2 emissions across the MENA panel of countries.

Table 4. Estimation of trend elasticity using FMOLS

Country	Trend elasticities by FMOLS	p
Algeria	0.712	~0
Bahrein	0.716	~0
Egypt	0.696	~0
Iran	0.734	~0
Iraq	0.720	~0
Jordan	0.681	~0
Kuwait	0.718	~0
Lebanon	0.678	~0
Libya	0.723	~0
Morocco	0.689	~0
Oman	0.706	~0
Qatar	0.722	~0
Saudi Arabia	0.723	~0
Syria	0.700	~0
Tunisia	0.679	~0
UAE	0.709	~0

Table 5. Estimation of trend elasticity using DOLS

Country	Trend elasticities by DOLS	p
Algeria	0.716	~0
Bahrein	0.710	~0
Egypt	0.697	~0
Iran	0.750	~0
Iraq	0.720	~0
Jordan	0.679	~0
Kuwait	0.716	~0
Lebanon	0.679	~0
Libya	0.723	~0
Morocco	0.702	~0
Oman	0.774	~0
Qatar	0.720	~0
Saudi Arabia	0.714	~0
Syria	0.700	~0
Tunisia	0.679	~0
UAE	0.726	~0

FMOLS and DOLS Econometric Estimation of the Trend Component

To estimate the Kuznets elasticity, FMOLS and DOLS are used, as they provide robust results and correct for violations of the assumptions (**Table 4** & **Table 5**).

FMOLS econometric estimation method

The trend elasticity estimated by FMOLS reflects a positive and significant long-run relationship between GDP and CO_2 emissions across the entire panel. The estimated elasticities range from 0.678 to 0.735, indicating that a 1% increase in GDP leads to a 0.678% to 0.735% increase in CO_2 emissions. These results indicate that elasticities are positive and below unity, suggesting relative, rather than absolute decoupling between economic development and climate change (**Figure 4**).

In this context, Morocco, with an elasticity of 0.689, occupies a favorable intermediate position, below the regional average and significantly lower than that observed in major oil-based economies such as Iran (0.735), Saudi Arabia (0.723), or Qatar (0.723). This relative performance can be interpreted as reflecting Morocco's efforts to diversify its energy mix and address climate change.

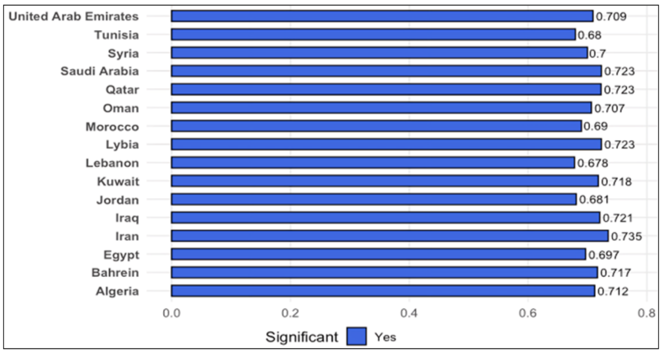

Figure 4. Estimated trend elasticities by FMOLS (Source: Authors' own elaboration)

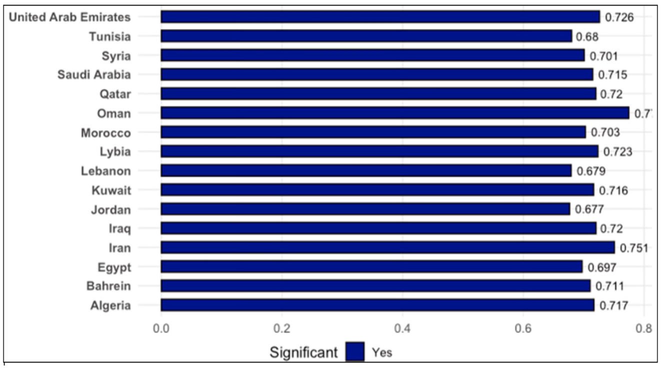

Figure 5. Estimated trend elasticities by DOLS (Source: Authors' own elaboration)

DOLS econometric estimation method

Similarly, the DOLS trend elasticity indicates a positive and significant long-run relationship between GDP and CO_2 emissions across the entire panel. The estimated elasticities range from 0.679 to 0.75, indicating that a 1% increase in GDP leads to a 0.679 % to 0.75 % increase in CO_2 emissions. These results also show that elasticities are positive and below unity, indicating relative, rather than absolute decoupling between economic development and climate change (**Figure 5**).

In this context, Morocco, with an elasticity of 0.702, occupies a favorable intermediate position, below the regional average and significantly lower than that observed in major oil-based economies such as Iran (0.75), Saudi Arabia (0.714), or Qatar (0.72). This relative performance can be interpreted as reflecting Morocco's efforts to diversify its energy mix and address climate change.

Comparison between FMOLS and DOLS methods

The results from FMOLS and DOLS indicate outcomes that are nearly identical for the MENA Region panel, reflecting an average relative decoupling between GDP and CO_2 emissions and confirming the historical existence of a long-run relationship. In this regard, the elasticity estimated by FMOLS is 0.689 for Morocco, while that estimated by DOLS is 0.702, showing a slight difference in the GDP-emissions relationship. This slight difference highlights that the DOLS method captures transient effects and annual fluctuations in growth and emissions more effectively, whereas FMOLS provides a robust measure of the long-run trend.

Policy Implications for Morocco and the MENA Region

The results suggest strong heterogeneity in the decoupling between CO_2 emissions and economic growth in the MENA Region, thereby implying the need for public policies tailored to the specific characteristics and priorities of countries in the region.

Encouraging the transition to renewable energy

Accelerating the energy transition toward clean energy in the MENA Region remains essential for achieving low-carbon economies. Morocco is committed through its energy and sustainable development strategies and has set ambitious targets for 2030 and 2035 for integrating various renewable energy sources into its energy mix. However, major emitters in the region should not only orient their public policies toward green energy transition strategies but also toward low-carbon-intensity strategies by establishing incentive mechanisms for investors in technological efficiency and green technologies.

Integrating climate commitments into sectoral strategies

The empirical results of this study indicate that although countries in the panel exhibit relative decoupling, they continue to increase GHG emissions in the absence of structural transformations. In this regard, high-emitting countries must imperatively integrate climate objectives into their national development strategies to ensure sustainable development for future generations. For Morocco, this implies adopting an enhanced ambition to achieve absolute decoupling by further promoting low-carbon industries.

Reducing regional disparities in the MENA Region

Countries in the MENA Region cannot adopt a uniform strategy for the entire region due to regional disparities in growth and economic development. However, they can draw inspiration from best practices implemented by the most advanced countries in combating climate change and promoting energy transition, such as Morocco.

Orienting public policies toward absolute decoupling

The results show that MENA countries are far from achieving absolute decoupling between growth and emissions. In this regard, countries must align their public policies with priority sectors for decarbonization. This notably involves implementing ambitious economic and fiscal policies and supporting the development and deployment of green technologies to promote sustained growth without compromising the environment.

Achieving absolute decoupling

To achieve absolute decoupling, Morocco has adopted in 2023, its low emissions development strategy (LEDS) by 2050, targeting carbon neutrality in the long term and updated its NDC 3.0. Under NDC 3.0 and LEDS by 2050, the country aims to reach carbon neutrality by 2050 and expand renewable electricity capacity to more than 50% by 2030 and progressively phase out coal by around 2050. However, despite these ambitious commitments, achieving absolute decoupling before 2040 remains unlikely under current policies. Morocco's energy system is still heavily dependent on coal, which accounted for a large share of electricity production and emissions in recent years. Therefore, while relative decoupling is already underway, absolute decoupling is more realistically achievable closer to 2050, in line with Morocco's long-term low-carbon strategy and net-zero ambition.

To reach the downward arm of the EKC earlier, additional structural measures would be necessary. First, accelerating the coal phase-out, as it remains the most carbon-intensive component of Morocco's energy mix. Second, accelerate the effective implantation of the green taxation system for companies, strengthen regulatory frameworks, and mobilizing international climate finance. This would help internalize environmental costs and shift investment toward low-carbon technologies. Third, boost the deployment of renewables and storage infrastructure combined with energy efficiency improvements would significantly reduce emissions intensity. Altogether, Morocco could reach absolute decoupling and firmly enter the EKC downward trajectory by 2050.

Role of the non-energy factors

Non-energy factors play a structurally significant role, yet often underappreciated in Morocco's emissions trajectory, and they are only partially and implicitly captured in standard CO_2-GDP elasticity estimates. First, Morocco's main activity is based on agriculture and land use. These sectors are major direct sources of GHG, but their emissions are largely non-CO_2 (methane and nitrous oxide). Agriculture alone accounts for roughly 23% of total emissions, making it the second-largest emitting sector after energy. These emissions are driven by fertilizer use (N_2O) and livestock (CH_4), not fossil fuel combustion, meaning they are decoupled from energy intensity and industrial growth patterns typically reflected in CO_2-GDP elasticity. At the same time, agriculture is highly sensitive to climate variability which affects productivity, rural income, and overall GDP fluctuations. This creates a two-way interaction: agriculture both contributes to emissions and amplifies macroeconomic volatility, but its structural emissions are not fully captured in CO_2-based elasticity metrics, which focus primarily on energy-related emissions.

Second, water stress introduces an indirect but increasingly important channel linking non-energy factors to emissions. Morocco faces chronic water scarcity, with agriculture consuming up to 80% of national water resources, and climate change is intensifying drought frequency and groundwater depletion. To cope, the country is investing heavily in desalination and water transfers, which are energy-intensive processes and therefore increase electricity demand and associated CO_2 emissions if powered by fossil fuels. Even when powered by renewables, they still reshape the energy demand structure. This means water scarcity acts as a feedback loop: it raises energy demand and emissions, which in turn affects the CO_2-GDP relationship.

In sum, while CO_2-GDP elasticity captures the energy-growth-emissions nexus, it underestimates Morocco's true emissions dynamics by overlooking structurally significant non-CO_2 emissions from agriculture and cross-sectoral pressures such as water scarcity that reshape energy demand. These factors imply that relying solely on CO_2-based decoupling metrics may give an incomplete picture of the country's environmental transition, especially in a climate-vulnerable economy like Morocco.

CONCLUSION

Climate change has become a major issue, as attention has shifted from merely mitigating GHG emissions to adapting populations to the effects accompanying this change, notably rising temperatures and biodiversity loss. Moreover, MENA countries face the dual challenge of accelerating economic development while complying with international climate commitments.

The preliminary analysis indicated strong heterogeneity within the panel regarding GHG emissions and GDP, suggesting that decoupling between economic growth and emissions depends primarily on long-term political, energy, and technological choices made by the countries concerned.

In this perspective, the continuation of efforts toward relative decoupling is essential but insufficient in the face of climate shocks. Therefore, absolute decoupling is necessary to sustainably dissociate CO_2 emissions from economic growth and constitutes not only a commitment but also a necessity to create a low-carbon world better adapted to current living conditions. This implies a radical long-term transformation through the widespread adoption of renewable energy, the introduction of energy efficiency principles, and the gradual abandonment of fossil fuels.

At the same time, the transition toward renewable energy offers opportunities for green job creation and the development of sustainable sectors. Investment in activities related to the energy and ecological transition is considered a structural lever for diversifying economic activity and reducing emissions. Countries that integrate these dimensions into their public policies and national strategies will be leaders in sustainability and, in the long term, global hubs and economic powers strongly reliant on renewable energy in a context marked by a gradual decline in fossil fuels.

Furthermore, the recent acceleration of renewable energy deployment in Morocco where installed capacity exceeds 45% and the electricity mix surpassed 46% in 2025, suggests a structural shift toward a lower-carbon growth model. In principle, such a transition is expected to reduce the long-run CO_2-GDP elasticity by decreasing the carbon intensity of economic activity. However, empirical results found based on the period 1990-2023 indicates that Morocco has not yet reached the turning point of the EKC. Indeed, the estimated long-run elasticity remains positive, with values of 0.689 (FMOLS) and 0.702 (DOLS), implying that economic growth continues to be associated with increasing emissions, and thus has not achieved absolute decoupling but only a relative one.

Nevertheless, Morocco, within its region and through pilot actions in the field of climate change, particularly demonstrates this green transition. Ensuring sustained economic growth alongside moderate carbon intensity reflects the country's strong willingness to explore its renewable energy potential and its capacity to transition toward absolute decoupling.

In conclusion, to ensure sustained economic growth in the MENA Region, countries must transform the climate challenge into a strategic opportunity and structure their economies around inclusive, low-carbon models. Achieving a negative trend elasticity, indicating absolute decoupling between emissions and GDP, constitutes both an economic and social obligation to chart a trajectory of growing economies and ensure resilient, sustainable development for future generations in the face of climate change crises.

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AI statement: The authors stated that generative AI tools were used only to assist with language editing and improving readability. The authors confirm that all scientific content, analysis, results, and conclusions are entirely original and developed independently by the authors. The use of AI-based tools did not influence the research design, data analysis, interpretation of results, or the scientific integrity of the work. The authors take full responsibility for the authenticity, originality, and accuracy of the manuscript.

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Data sharing statement: Data supporting the findings and conclusions are available upon request from corresponding author.

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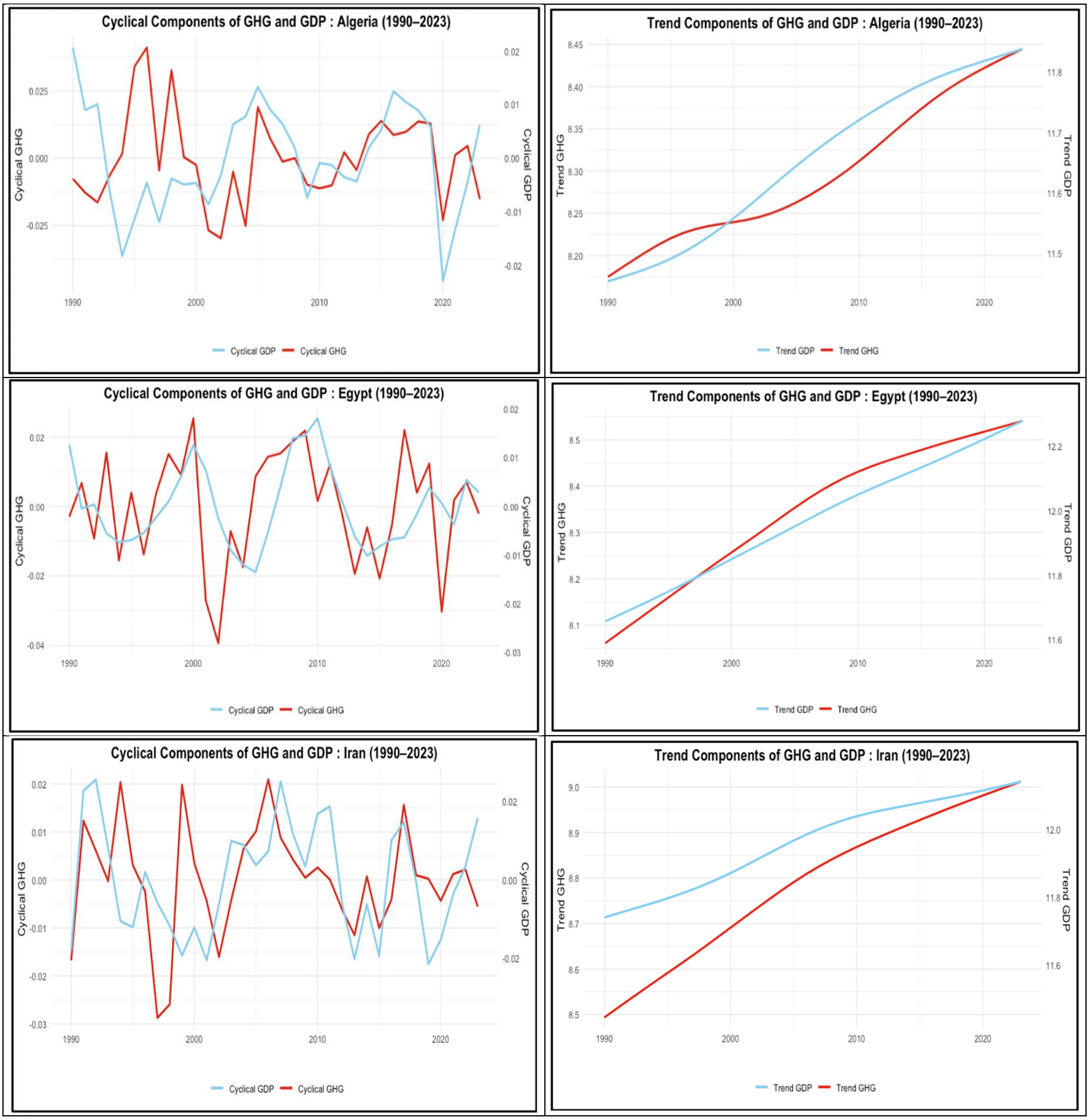
APPENDIX A: CYCLICAL AND TREND COMPONENTS OF THE LOGARITHM OF CO_2 EMISSIONS (TONS) AND THE LOGARITHM OF GDP ($ PPP CONSTANT INTERNATIONAL OF 2011) FOR SELECTED COUNTRIES IN THE PANEL



(Source: Authors' own elaboration)

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