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Understanding the Interplay between Economic Growth and Environmental Dynamics: Insights from the Moroccan Context through an ARDL Model

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Abstract: This study investigates the dynamics of economic growth and the environment in the context of Morocco using an Autoregressive Distributed Lag (ARDL) model. The research aims to shed light on the relationship between economic development and environmental degradation, as well as to explore the applicability of the Environmental Kuznets Curve (EKC) hypothesis.
Moving to the empirical analysis, the study utilizes an ARDL model to estimate the relationship between economic growth and environmental indicators in both the short run and the long run. The findings suggest a U-shaped relationship between economic growth and environmental indicators in the short run, while in the long run, economic growth shows an inverted U-shaped relationship with environmental degradation. These results align with the theoretical framework of the EKC hypothesis.

Keywords: Environmental Kuznets Curve (EKC); Economic growth; green employment; energy consumption per capita; ARDL Model.

JEL Classification: O44, O13, Q56, C32, C51

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1 Introduction

Energy consumption plays a crucial and multifaceted role in both economic growth and environmental sustainability. On one hand, the production and consumption of energy are essential drivers of economic growth, as they fuel industries, enable technological advancements, and support various sectors of the economy. However, it is important to acknowledge that energy-related activities also have adverse effects on the environment, primarily through the emission of pollutants and greenhouse gases.
Recognizing the intricate interplay between energy consumption, economic growth, and environmental concerns, scholars such as Van der Ploeg and Withagen (1991) emphasize that any analysis of energy consumption and economic growth must take into account environmental considerations. This viewpoint aligns with the insights provided by Grossman and Krueger (1994), who extensively studied the Environmental Kuznets Curve (EKC).

The EKC framework explores the relationship between economic growth and environmental degradation, suggesting that as economies develop and reach a certain income level, environmental quality can improve.
In the context of Morocco, like many other developing countries, the country is grappling with the challenge of reconciling economic growth aspirations with the need to safeguard the environment. Despite the negative externalities associated with population growth and industrialization, Morocco is actively pursuing strategies and plans aimed at preserving the delicate balance between economic progress and environmental sustainability. These efforts reflect the country's commitment to promoting sustainable development practices and mitigating the environmental impact of energy consumption, thus contributing to the global transition towards a greener and more sustainable future.
In light of these considerations, it is pertinent to explore the following questions:

- What is the nature of the relationship between the environment and economic growth specifically in the context of Morocco?
- Does the evidence support the existence of an Environmental Kuznets Curve phenomenon in Morocco?

The objective of this article is to investigate the evolving relationship between economic growth and the environment over time. To achieve this goal, the article is structured into three main sections.
In the first section, we delve into the theoretical aspects pertaining to the Environmental Kuznets Curve (EKC) and examine existing empirical studies. We explore the fundamental concepts of the EKC, which posits a connection between economic development and environmental degradation. Initially, as an economy grows, environmental degradation tends to increase. Additionally, we review pertinent empirical studies that have explored this relationship, shedding light on the applicability and validity of the EKC.
Moving on to the second section, we outline the methodology employed for this study. We clarify the selection process for economic and environmental indicators, elucidate the data collection methods utilized, and provide details on any statistical or econometric techniques employed. A robust and transparent methodology is crucial to ensure the reliability and significance of our findings.
Finally, in the third section, we undertake an econometric analysis. By applying statistical models to the collected data, we estimate the relationship between economic growth and environmental indicators. Through this analysis, our aim is to contribute empirical evidence that elucidates the dynamics between economic growth and the environment, thereby enhancing our understanding of this complex relationship.

2 Literature review

The empirical literature review reveals optimistic findings that support the relationship between economic growth and the environment. Numerous studies have demonstrated the existence of an inverted "U"-shaped relationship, known as the "Environmental Kuznets Curve" (EKC), between natural resource use, income, and environmental quality.
The pioneering work of Grossman and Krueger (1994) examined the environmental impacts of the North American Free Trade Agreement (NAFTA) by analyzing sulfur dioxide (SO2) as an environmental variable. They identified turning points in the EKC between $4,000 and $5,000.
It is worth noting that the presence of the EKC is not always observed in heterogeneous data but is almost always observed for homogeneous and uniform countries. The income levels at which pollution reaches its maximum were found to be around $8,700 for SO2, $11,200 for nitric oxide (NO), $10,300 for suspended particulate matter (SPM), and $5,600 for carbon dioxide (CO2). List and Gallet (1999) examined the period from 1929 to 1994 in the United States and identified an inverted "U"-shaped relationship between growth and pollution for per capita SO2 and NO. These findings highlight the diverse results regarding the EKC across different pollutants and countries. The existence and shape of the EKC depend on various factors, including the specific pollutant, the level of economic development, and the unique context of each country or region.
Similar findings have been observed by Hill and Magnani (2000) and Millimet et al. (2000), supporting the relationship between economic growth and the environment. However, Cole et al. (1997) provide a nuanced perspective by analyzing the relationship between various environmental elements, such as SPM, SO2, NO, methane emissions, etc. They concluded that the EKC is only satisfied for certain pollutants, and the environmental variables for which the EKC is not always satisfied often have very high or even nonexistent turning points.

According to Grossman and Krueger's (1994) article on the Environmental Kuznets Curve (EKC), which examines the correlation between per capita income and the environment, the authors noted a positive relationship between short-term economic growth and pollution levels. However, they found that beyond a certain income threshold, further economic growth was accompanied by a decline in pollution levels. These findings have been supported by subsequent studies (Su and Chen, 2018; Sarkodie and Strezov, 2019).

The Kuznets curve consists of three distinct phases. The first phase corresponds to the pre-industrial economy, where the focus is on development and poverty alleviation. During this stage, natural resources, especially energy, are extensively utilized, resulting in adverse environmental effects. Consequently, there exists a positive and escalating correlation between economic growth and the release of pollutants that degrade the environment.

The second phase marks the transition from a primary to an industrialized economy and is often referred to as the "transition phase." This phase is characterized by a surge in energy resource consumption, leading to a peak in environmental pollution, as depicted by the apex of the inverted "U"-shaped curve. However, once a certain level of prosperity is attained, the economy strives for a healthier environment and initiates a transition towards greener energy technologies, aiming to reduce pollution in its activities.

The final phase corresponds to the post-industrial economy, where pollution control measures become a priority. During this phase, a linear and negative relationship is observed between the evolution of wealth and environmental pollution.

Countries with larger income disparities between economies tend to have higher inflection points, unlike countries with lower income disparities. This finding is consistent with the results of List and Gallet (1999) and Stern and Common (2001). However, Hill and Magnani (2002) demonstrate that the EKC is satisfied for a panel of 156 countries. Nevertheless, when estimates are made separately for high, middle, and low-income country groups, the EKC is not uniformly satisfied. To obtain more robust results, several studies have introduced additional control or discriminatory variables, such as political factors (Torras and Boyce, 1998), trade factors (Panayotou, 1997), or energy factors (Jobert and Karanfil, 2010).

Nishide and Ohyama (2010), Pandit and Paudel (2016), Sinha and Bhattacharya (2017), and Sarkodie and Strezov (2019) indicate the probable existence of an inverted "N"-shaped relationship between economic development and environmental pollution, as demonstrated by Dogan and Seker (2016) as well. Berthe and Elie (2015) acknowledge the presence of heterogeneity in the results, particularly related to the endogenous variables used, and no clear trend has been identified for CO2 emissions, air pollution, and water pollution. However, the authors recognize that a significant number of empirical results align with the theoretical analyses of Boyce (1994), Magnani (2000), and Wilkinson and Pickett (2010), which acknowledge that income inequalities have a negative impact on the environment.

The energy structure is a crucial factor extensively studied in the literature on the determinants of CO2 emissions (Omri, Belaïd, 2020). Research in this context recognizes the inverse relationship between renewable energy consumption and CO2 emissions. A recent empirical study conducted by Cerdeira et al. (2016) on the period 1960-2011 confirms these results for Italy, stating that per capita renewable electricity production reduces per capita CO2 emissions in Italy in the short and long term. This finding aligns with the findings of Gozgor (2018) for the case of the United States.

Williamson (1965) discusses regional inequality patterns within countries during the process of national development. Galor and Zeira (1993) explore the relationship between income distribution and macroeconomics, emphasizing the role of inequality in economic growth. Li and Zou (1998) argue that income inequality is not necessarily detrimental to economic growth, providing theoretical reasoning and empirical evidence. Milanovic (2000) tests the median-voter hypothesis, income inequality, and income redistribution, while Firebaugh (2003) analyzes the changing patterns and dynamics of global income inequality. Perotti (1996) examines the relationship between growth, income distribution, and democracy. Forbes (2000) reevaluates the relationship between inequality and economic growth, challenging previous views. Easterly (2007) argues that inequality causes underdevelopment, supported by empirical analysis. Bourguignon (2015) focuses on the globalization of inequality, exploring its influence on income distribution. Barro (2000) uses panel data to analyze the relationship between inequality and growth. Piketty and Saez (2003) study income inequality in the United States over time. Milanovic, Lindert, and Williamson (2011) examine pre-industrial inequality patterns. Azam and Gurgand (2008) investigate the economic incentives and implications of being a local official in rural China. Chetty, Hendren, Jones, and Porter (2020) explore intergenerational perspectives of race and economic opportunity in the US. Autor

(2019) discusses the changing nature of work and its impact on labor markets. Piketty (2020) delves into the historical and contemporary dimensions of capital and inequality. Acemoglu and Restrepo (2019) analyze the relationship between automation, labor, and technological advancements.

Matthew (2004) provides empirical evidence on the relationship between population size, demographic factors, and pollution. The study rejects the hypothesis of a link between pollution and urban growth, aligning with the findings of Rosa and Dietz (1997), York et al. (2003), Shi (2003), and Copeland and Taylor (2004). Copeland and Taylor's econometric analysis supports a "U-shaped" curve, indicating that the environmental policy variable does not significantly affect trade and investment flows.

Contrarily, Hanna and Oliva (2015) find no relationship between pollution and the labor factor as a driver of growth in Mexico.

He (2006) focuses on China and investigates the relationship between economic growth and the environment, particularly examining the effects of energy, transportation, and foreign trade on local air pollution emissions. The analysis reveals an inverted U-shaped relationship for sulfur dioxide but a U-shaped curve for soot particles, suggesting that soot particles, such as black carbon, may pose a more significant environmental concern in China than sulfur dioxide.

Martinez-Zarzoso and Maruotti (2011) analyze the impact of urbanization on CO2 emissions in developing countries from 1975 to 2003. Their study contributes to the literature by establishing a U-shaped relationship between urbanization and CO2 emissions.

Roca (2002) conducts an econometric analysis on individual preferences and environmental quality, finding a U-shaped curve, indicating varying considerations of environmental costs.

Overall, limited research exists on the relationship between economic growth and pollution determinants, particularly in the context of Morocco. Thus, this study aims to bridge this gap by providing additional evidence to the existing literature

3 Methodology

The paper proposes an improved econometric estimation methodology for analyzing time series data based on a well-established modeling framework. Specifically, we aim to investigate the relationship between economic growth and environmental pollution by employing the Environmental Kuznets Curve (EKC) model, as originally proposed by Grossman and Krueger (1994) and later extended by Dinda (2003).

The equation of the EKC model takes the following form:

$$Y_{it} = \alpha + \beta_1 x_{1t} + \beta_2 x_{1t}^2 + \beta_3 x_{3t} \ldots \beta_p x_{pt} + \varepsilon_t \quad \textbf{(1)}$$

In this study, we focus on CO_2 emissions in kilotonnes as our pollution indicator, denoted as Y_{it}. To capture the relationship between pollution and economic growth, previous literature has commonly employed cubic or quadratic models. However, in our analysis, we adopt a second-order model, as suggested by Dinda (2003), where x_{1t} and x_{2t}represent economic growth indicators measured by constant gross domestic product (GDP).

To account for additional factors that may influence pollution levels, we include two exogenous variables in our analysis: energy consumption per capita, the trade ratio, urban population and Employment. These variables are incorporated into the EKC model to enhance the robustness and comprehensiveness of our analysis.

By employing this methodology, we aim to provide a more accurate and nuanced understanding of the relationship between economic growth and environmental pollution, specifically focusing on CO_2 emissions. Our approach accounts for multiple factors, such as economic growth, energy consumption, and trade, to capture the complexity of this relationship and provide valuable insights for policymakers and researchers in the field of environmental economics.

The different forms of relationship can be defined as follows Lamzihri and al. (2022):

- Si $\beta_1 = 0$ et $\beta_2 = 0$: There is no relationship between economic growth and the environmental variable
- Si $\beta_1 > 0$ et $\beta_2 = 0$: There is a positive relationship between economic growth and the environmental variable
- Si $\beta_1 < 0$ et $\beta_2 = 0$: There is a negative relationship between economic growth and the environmental variable

- Si $\beta_1 < 0$ et $\beta_2 > 0$: There is a U-shaped relationship between economic growth and the environmental variable
- Si $\beta_1 > 0$ et $\beta_2 < 0$: There is an inverted U-shaped relationship between economic growth and the environmental variable, indicating acceptance of the Kuznets approach

The main variables commonly used to explain CO2 emissions are the level of wealth or economic growth (Grossman, Helpman, 1995; Ridzuan, 2019), energy structure (Cerdeira et al., 2016; Gozgor, 2018), international openness (Aklin, 2016; Baek et al., 2009; Cole, 2004), and more recently, eco-innovation (Du et al., 2019; Mongo et al., 2021).

All the variables of the model are presented in the table below:

Table 1: Definition of the variables

Variables	Definition	Source	Abréviation	Type
Carbon dioxide emissions	Represents the emission of CO2 gas into the Earth's atmosphere (INSEE).	International Energy Agency - AIE	**LECO2**	Endogenous variable
Economic growth	Represents the evolution of produced wealth (World Development Indicators - WDI).	Banque Mondiale - World Development Indicators	**LGDP**	Exogenous variable
Energy consumption per capita	An indicator measuring energy expenditures per individual (OECD).	International Energy Agency - AIE	**LEC**	Exogenous variable
Trade to GDP	Measures the level of openness of a country towards the rest of the world.	Banque mondiale- World Development Indicators	**LT**	Exogenous variable
Urban population	the number of people living in areas classified as urban (World Development Indicators - WDI).	Banque mondiale- World Development Indicators	**LUP**	Exogenous variable
Green employment	refers to jobs that are directly or indirectly associated with environmentally friendly or sustainable activities, industries, or sectors (World Development Indicators - WDI).	Banque mondiale- World Development Indicators	**LGEMP**	Exogenous variable

Source: Authors

In this study, we analyze data from the period of 1990 to 2020 to investigate the relationship between economic growth, exports, imports, carbon dioxide emissions, Urban population, employment and per capita energy consumption. We obtained economic growth indicators (GDP r and GDP n), exports, imports, Urban population and employment from the World Bank's WDI database. Carbon dioxide emissions and per capita energy consumption data were sourced from the IEA database. To ensure data homogeneity and remove the time effect, we applied the natural logarithm (ln) transformation to all variables. To test the Environmental Kuznets Curve hypothesis, we employed the ARDL approach (Pesaran and al., 2001) and Lamzihri and al., 2021, which was chosen based on the stationarity of the variables, as presented in the results section.

4 Results and discussion

4.1 Descriptive statistics:

The table presents summary statistics and a Jarque-Bera test for normality for various variables, including energy consumption per capita (LEC), carbon dioxide emissions ($LECO_2$), economic growth (LGDP), economic growth squared ($LGDP^2$), green employment (LGEMP), trade (LT), and urban population (LUP). The mean values represent the average levels of each variable, while the standard deviation measures the dispersion of data around the mean. Importantly, all variables exhibit mean values higher than their respective standard deviations, suggesting that the data is suitable for analysis. The Jarque-Bera test assesses the normality of the data distribution, and higher test values indicate a higher acceptance of normality. The associated probabilities provide insights into the likelihood of observing the test statistics assuming a normal distribution.

Table 2: Descriptive statistics

	LEC	LECO2	LGDP	LGDP2	LGEMP	LT	LUP
Mean	13,04901	10,65218	24,91977	49,81486	10,64334	0,62832	16,64749
Std. Dev.	0,46033	0,361744	0,361595	0,77163	0,115682	0,227281	0,193984
Jarque-Bera	2,519727	2,399063	2,534417	1,194475	3,98356	3,710322	1,504911
Probability	0,178567	0,301335	0,281617	0,55033	0,136452	0,156428	0,471208

Source: Authors, Eviews

4.2 Correlation

The correlation table reveals the relationships between various variables. Carbon dioxide emissions (LECO2) show a strong positive correlation of 76% with energy consumption per capita (LEC), indicating that higher energy consumption is associated with increased CO2 emissions. Economic growth (LGDP) demonstrates a significant positive correlation of 99% with both carbon dioxide emissions (LECO2) and economic growth squared (LGDP2), suggesting that economic growth is linked to higher CO2 emissions and that the relationship may be non-linear. Additionally, economic growth (LGDP) exhibits a strong positive correlation with trade (LT) and urban population (LUP), indicating a connection between economic growth and increased trade activity and urbanization. Green employment (LGEMP) displays a notable negative correlation of -90% with economic growth (LGDP), implying that as economic growth expands, green employment decreases.

Table 3: Correlation matrix

	LECO₂	**LEC**	***LGDP***	***LGDP²***	***LGEMP***	***LT***	***LUP***
LECO₂	100%						
LEC	76%	100%					
LGDP	99%	80%	100%				
LGDP²	99%	72%	99%	100%			
LGEMP	-90%	-85%	94%	91%	100%		
LT	90%	71%	90%	88%	-81%	100%	
LUP	99%	79%	99%	99%	-94%	87%	100%

Source: Authors, Eviews

4.3 Stationarity of the variables:

To ensure the reliability of our model estimation and examine the long-term relationship among the variables, we first addressed the issue of stationarity in the time series. Using the Augmented Dickey-Fuller (ADF) test, as presented in Table 4, we assessed the stationarity properties of the variables. Our results reveal that "LGDP & LECO2" display stationarity in first difference (I(1)), indicating the need for differencing to achieve stationarity. In contrast, the remaining variables exhibit stationarity at the level (I(0)), suggesting no differencing is required. With stationarity addressed, we can confidently proceed to estimate the model and explore the long-term dynamics among the variables. In our study, the suitable model is the Autoregressive Distributed Lag (ARDL) model.

Table 4: Stationarity with Augmented Duckey Fuller - ADF

	Level		**1st Diff**		**Decision**
Variables	**T, Stat**	**p-Value**	**T, Stat**	**p-Value**	
LGDP	-0,935371	0,9348	-11,69651	0	*I(1)*
LGDP2	-5,488756	0,0011	-	-	*I(0)*
LEC	-5,691337	0,0004	-	-	*I(0)*
LECO2	-1,572695	0,779	-4,99954	0,0022	*I(1)*
LT	-3,692244	0,0391	-	-	*I(0)*
LUP	-4,830954	0,0029	-	-	*I(0)*
LGEMP	-4,460059	0,0001	-	-	*I(0)*

Source: Authors, Eviews

4.4 Long-term relationship test:

In order to examine the existence of a long-term relationship among the variables, we conducted a cointegration test using the Bound test approach. The results of the test reveal a significant long-term relationship, as evidenced by the calculated Fisher statistic (F-stat = 5.32), which surpasses the critical values at all conventional significance levels (1%, 5%, and 10%). These findings, presented in the table below, provide strong evidence of a stable long-term relationship among the variables under consideration.

Table 5: Cointegration test

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	**5.325522**	10%	2.254	3.388
		5%	2.685	3.96
Actual Sample Size	29	1%	3.713	5.326

Null Hypothesis: No levels relationship

Source: Authors, Eviews

4.5 Model Estimation:

- **Short-run model:**

The coefficient values provide insights into the direction and magnitude of the impact. The constant term is 0.747, suggesting a baseline level of carbon dioxide emissions in the short run.

Changes in carbon dioxide emissions in the previous period $\Delta dLECO_{2\ (-1)}$ have a negative coefficient (-1.281), indicating that if carbon dioxide emissions were higher in the previous period, there is a tendency for them to decrease in the current period.

Changes in economic growth $\Delta LGDP$ have a positive coefficient (0.205), suggesting that an increase in economic growth leads to a rise in carbon dioxide emissions in the short run.

The squared term of economic growth $LGDP^2$ has a negative coefficient (0.162), indicating a non-linear relationship where initially, economic growth may decrease carbon dioxide emissions, but beyond a certain point, further economic growth reduces emissions.

Energy consumption per capita LEC, green employment $LGEM$, trade LT, and urban population LUP all have negative coefficients (-0.026, -0.1977, 0.041, and 0.58, respectively), suggesting that increases in these variables are associated with lower carbon dioxide emissions in the short run.

Table 6: Short-run model

Variable	Coefficient	t-Statistic	Prob.
C	0.747027	0.172941	0.0044
D(LECO2(-1))*	-1.281524	-6.331648	0.0000
D(LGDP)**	0.205951	1.015180	0.0216
LGDP2**	-0.162210	-1.288355	0.0116
LEC**	-0.026487	-0.856429	0.0014
LGEMP**	-0.197744	-1.065108	0.0089
LT**	0.041348	0.567692	0.0063
LUP**	0.582786	1.234185	0.0308

R-squared	0,694588
F-statistic	12,91528

Source: Authors, Eviews

Short-run equation:

$LECO_{2\ t} = 0.747 + 1.281\ \Delta dLECO_{2\ (-1)} - 0.205\ \Delta dLGDP + 0.162\ LGDP^2 - 0.026\ LEC - 0.1977\ LGEMP + 0.041\ LT + 0.58\ LUP$ **(2)**

- **Long-run model:**

Specifically, an increase in economic growth $\Delta LGDP$ leads to a decrease in carbon dioxide emissions, as indicated by the negative coefficient (-0.16). The squared term of economic growth $LGDP^2$has a positive coefficient (0.126), suggesting a non-linear relationship where initially, economic growth may increase carbon dioxide emissions, but beyond a certain point, further economic growth reduces emissions.

Energy consumption per capita LEC has a negative coefficient (-0.0206), indicating that higher energy consumption per capita contributes to higher carbon dioxide emissions. Green employment $LGEM$ also has a negative coefficient (-0.154), suggesting that an increase in green employment is associated with lower carbon dioxide emissions.

Trade LT, and urban population LUP both have positive coefficients (0.032 and -0.454, respectively), implying that higher levels of trade and urban population are associated with increased carbon dioxide emissions.

Table 7: Long-run model

Variable	Coefficient	t-Statistic	Prob.
D(LGDP)	-0.160708	-1.039633	0.0103
LGDP2	0.126576	1.296351	0.0089
LEC	0.020668	0.848628	0.0057
LGEMP	-0.154304	1.060864	0.0008
LT	0.032265	-0.565288	0.0079
LUP	-0.454760	-1.245744	0.0266
C	0.582921	-0.172657	0.0046

R-squared	0,756451
F-statistic	16,24664

Source: Authors, Eviews

Long-run equation:

$$LECO_{2\ t} = 0.582 - 0.16\ \Delta LGDP + 0.126\ LGDP^2 - 0.0206\ LEC - 0.154\ LGEMP + 0.032\ LT - 0.454\ LUP \quad \textbf{(3)}$$

4.6 Robustness of the model:

To ensure the reliability and robustness of our model, we conducted a series of tests to assess its validity. Firstly, we performed tests for Normality to verify if the model's error terms follow a normal distribution. This is important as it ensures that our statistical inferences are valid. Secondly, we tested for Heteroscedasticity, which examines if the variance of the error terms is consistent across different levels of the independent variables. Detecting Heteroscedasticity helps us determine if the model's assumptions are violated and if adjustments need to be made. Additionally, we examined Autocorrelation of errors to check if there is any correlation between the error terms at different time periods, as this can impact the model's efficiency and reliability. Lastly, we assessed Model stability to determine if the relationships between the variables hold consistently over time.

4.6.1 Normality:

According to the results of the Jarque-Bera test (Figure 1), the calculated probability is found to be greater than the 5% significance level. This suggests that the model adheres to a normal distribution.

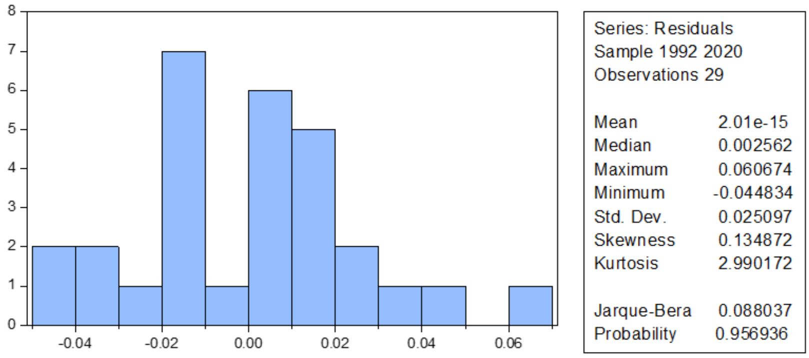


Figure 1: Jarque-Bera test

Source: Authors, Eviews

4.6.2 Heteroscedasticity:

To examine the presence of heteroscedasticity in our model, we conducted a Breusch-Pagan-Godfrey test. The test results indicate that the Chi-Square probability value is greater than 5%. Consequently, we reject the null hypothesis, which assumes the presence of heteroscedasticity, and accept the alternative hypothesis that the model is homoscedastic. This implies that the variance of the error terms in our model is constant across different levels of the independent variables.

Table 8: Breush-Pagan-Godfrey test

F-statistic	1,322945	Prob. F(7,21)	0,2883
Obs*R-squared	8,874833	Prob. Chi-Square(7)	0,2618
Scaled explained SS	4,630879	Prob. Chi-Square(7)	0,7049

Source: Authors, Eviews

4.6.3 Autocorrelation of the residuals:

Based on the results of the Breusch-Godfrey test, which examines the presence of autocorrelation in the residuals of the model, the probability value obtained is greater than 5%. Therefore, we reject the null hypothesis and accept the alternative hypothesis that the residuals of the model are not autocorrelated. This implies that there is no significant correlation between the error terms at different time periods, suggesting that the model adequately captures the underlying dynamics of the data.

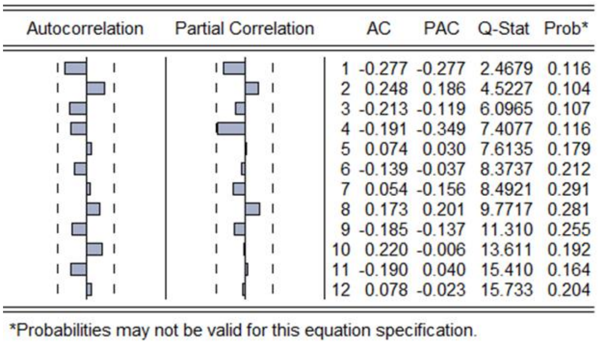
Table 9: Breush -Godfrey test

F-statistic	2,558001	Prob. F(2,19)	0,1038
Obs*R-squared	6,152101	Prob. Chi-Square(2)	0,1461

Source: Authors, Eviews

4.6.4 Residual correlogram:

Based on the analysis of the correlogram, we observe that all the bars representing the autocorrelation coefficients fall within the confidence interval. This indicates that the residuals of the model exhibit stability over time. The fact that the autocorrelation coefficients do not significantly deviate from zero suggests that there is no systematic pattern or correlation present in the residuals at different lags.



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.277	-0.277	2.4679	0.116
		2	0.248	0.186	4.5227	0.104
		3	-0.213	-0.119	6.0965	0.107
		4	-0.191	-0.349	7.4077	0.116
		5	0.074	0.030	7.6135	0.179
		6	-0.139	-0.037	8.3737	0.212
		7	0.054	-0.156	8.4921	0.291
		8	0.173	0.201	9.7717	0.281
		9	-0.185	-0.137	11.310	0.255
		10	0.220	-0.006	13.611	0.192
		11	-0.190	0.040	15.410	0.164
		12	0.078	-0.023	15.733	0.204

*Probabilities may not be valid for this equation specification.

Figure 2: Residual correlogram

4.6.5 Model stability:

The CUSUM test supports the findings from the correlogram analysis. By examining the blue curve, we can observe that it remains within the 5% interval. This indicates that the coefficients of the model remain stable over time. The fact that the curve stays within the confidence interval suggests that there is no significant cumulative deviation or structural change in the coefficients of the model.

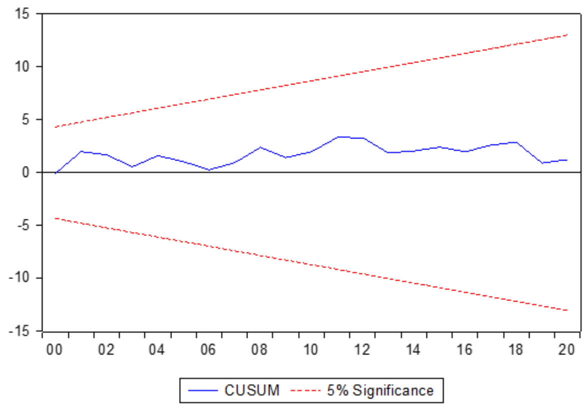


Figure 3: CUSUM test

Source: Authors, Eviews

5 Conclusion

In the short run, it is observed that changes in economic growth have a positive impact on carbon dioxide emissions, indicating that as the economy grows, emissions tend to increase. However, the squared term of economic growth introduces a non-linear relationship, suggesting that beyond a certain threshold, further economic growth leads to a reduction in emissions. This implies that policymakers should focus on promoting sustainable economic growth that is less reliant on carbon-intensive activities. Energy consumption per capita and green employment both have negative coefficients, indicating that increasing energy efficiency and adopting environmentally green employment practices can contribute to lower carbon dioxide emissions in the short run. This highlights the importance of implementing energy conservation measures and promoting green job creation in industries that have a lower environmental impact.

Trade and urban population have mixed effects on carbon dioxide emissions in the short run. While trade shows a positive coefficient, indicating that increased trade activities may contribute to higher emissions, the coefficient for urban population is negative, suggesting that higher urbanization levels are associated with lower emissions. Policymakers should focus on managing the environmental impact of trade activities and urban development through the implementation of sustainable practices and policies.

In the long run, economic growth exhibits a negative coefficient, implying that sustained economic growth is associated with lower carbon dioxide emissions. The squared term of economic growth reinforces this relationship, indicating an inverted U-shaped pattern where beyond a certain point, further economic growth leads to emissions reduction. This supports the Environmental Kuznets Curve hypothesis, which suggests that as economies develop, they tend to transition to cleaner and more sustainable practices. Energy consumption per capita and green employment continue to have negative coefficients in the long run, emphasizing the importance of promoting energy efficiency and environmentally friendly employment practices to achieve long-term emissions reduction. Trade and urban population remain influential in the long run, with positive and negative coefficients, respectively. Policymakers should implement measures to manage the environmental impact of trade activities while adopting sustainable urban development strategies to mitigate carbon dioxide emissions.

Based on these findings, it is recommended that Moroccan policymakers prioritize sustainable economic growth, energy conservation, promotion of green employment, and sustainable trade and urbanization practices. This could be achieved through the implementation of policies that incentivize renewable energy adoption, energy efficiency programs, investment in sustainable infrastructure, and the promotion of sustainable urban planning and transportation systems. Additionally, fostering green job creation and promoting sustainable trade practices can contribute to reducing carbon dioxide emissions in the long run while supporting economic development and environmental sustainability goals.

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