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Carbon Emissions, Energy Consumption, and Economic Growth in Morocco

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ABSTRACT

This study examines the relationship between carbon emissions, energy consumption, and economic growth in Morocco from 1990 to 2021. The ARDL technique was employed to analyze the long and short-term relationships among the variables. Results reveal a long-term relationship between carbon emissions, energy consumption, and economic growth in Morocco. Additionally, economic growth was found to have a positive and significant impact on carbon emissions both in the short and long term, supporting the Environmental Kuznets Curve hypothesis. Policymakers and governments must prioritize investments in energy efficiency improvements and carbon emissions reductions through effective environmental policies and infrastructure investments while emphasizing alternative and renewable energy sources.

Keywords: Carbon Emissions, Economic Growth, Energy Consumption, ARDL Technique, Morocco
JEL Classifications: C32, O44, Q43, N57

1. INTRODUCTION

Climate change and its impact on the environment have become one of the biggest challenges facing our world today (Gahlawat and Lakra, 2020). One of the major contributors to this phenomenon is the increase in greenhouse gas emissions, particularly carbon dioxide (CO_2), which is largely attributed to the consumption of energy (Driga and Drigas, 2019). The relationship between CO_2 emissions, energy consumption, and economic growth is complex, as economic growth often leads to an increase in energy consumption and thus, higher CO_2 emissions. However, this relationship also raises concerns as increasing CO_2 emissions can have significant environmental and human health implications. Therefore, it is crucial to strike a balance between economic growth, energy consumption, and CO_2 emissions to promote sustainable development.

Studying the correlation between economic growth and carbon emissions is an essential aspect that highlights the trade-off between economic progress and environmental harm. The expansion and development of economies often result in a rise in carbon emissions, which in turn lead to ecological degradation. As economies grow and develop, there is often a corresponding increase in carbon emissions, leading to environmental degradation (Islam et al., 2021; Onofrei et al., 2022). This interplay between economic development and environmental impact raises important questions about the trade-off between boosting the economy and preserving the planet. Understanding this relationship is decisive for policymakers and individuals alike as they seek to strike a balance between economic growth and environmental sustainability. This area of study sheds light on the complex interplay between economic and environmental factors and provides important insights into how we can achieve both economic prosperity and environmental protection (Awan, 2013; Ma and Jiang, 2019).

Indeed, climate change has become a major concern worldwide, and Morocco is no exception. Morocco has experienced significant economic growth over the years, but this growth has also been accompanied by a staggering increase in carbon emissions of

43.9 metric tons per capita. The country has thus found itself at the 7th rank of the world's most polluting energy producers (Burck et al., 2023). For this purpose, the relationship between carbon emissions and economic growth has received considerable attention in the economic literature, which has examined whether carbon emissions have a positive, negative, or null effect on economic growth.

The objective of this study is to investigate the relationship between economic growth and carbon emissions in Morocco, covering the period from 1990 to 2021. Our study differs from earlier studies that only focused on the correlation between economic growth and carbon dioxide emissions in Morocco (Berahab, 2017; Bensbahou and Seyagh, 2020). Instead, we investigate the impact of energy consumption as an additional variable that contributes to carbon dioxide emissions. By including energy consumption in our analysis, we aim to provide a more comprehensive understanding of the factors that affect carbon dioxide emissions. Our approach acknowledges the complex interplay between economic growth, energy consumption, and carbon dioxide emissions, which has major implications for policymakers in Morocco and helps in designing sustainable development policies that balance economic growth with environmental protection.

The remainder of this paper is organized as follows. Section 2 briefly describes the literature review. Section 3 presents the models, estimation methods, and data sources. Empirical results are presented in Section 4. Section 5 discusses the results, and concludes.

2. LITERATURE REVIEW

The literature exploring the relationship between economic growth, energy consumption, and environmental degradation can be broadly classified into two categories. The first focuses primarily on testing the validity of the Environmental Kuznets Curve (EKC) hypothesis, which pertains to the relationship between environmental degradation deterioration and development. The EKC hypothesis was first proposed by Kuznets (1955) who observed that the relationship between per capita income and income inequality is U-shaped. As per capita income increases, income inequality initially rises and then starts declining after a turning point, forming a bell-shaped curve. This relationship between per capita income and income inequality was later extended to the relationship between environmental degradation and per capita income, with evidence suggesting that the two follow a similar U-shaped pattern. Thus, the EKC has become a useful tool for describing the relationship between environmental quality indicators, such as carbon dioxide and sulfur dioxide, and per capita income. The second concerns the relationship between energy consumption and economic growth (Kraft and Kraft, 1978; Masih and Masih, 1996). This interdependence implies that economic growth and energy consumption may go hand in hand, and efficient energy utilization depends on economic development (Yang, 2000; Wolde-Rufael, 2006; Narayan et al., 2008; Liang and Yang, 2019).

The relationship between economic growth and environmental degradation, as measured by pollution indicators, is widely discussed in the literature. The EKC hypothesis was first proposed and tested by Grossman and Krueger (1991) who aimed to assess the environmental effects on North American nations. They used three air pollutants in 42 countries' urban areas to investigate the connection between air pollution and economic growth. The study showed that while pollution rises with per capita GDP at low-income levels, it decreases with GDP growth at higher incomes. Stern (2004) and Dinda (2005) confirmed these findings through theoretical analysis and extensive surveys.

Coondoo and Dinda (2007) investigated the relationship between carbon dioxide emissions and income growth, with a focus on cross-country distribution patterns. They used the Johansen cointegration technique and found that inter-country income inequality significantly affects emissions. Akbostancı et al. (2008) tried to establish the Environmental Kuznets Curve (EKC) hypothesis in Turkey but failed to find a U-shaped relationship between environmental degradation and income.

Aslan et al. (2018) evaluated the Environmental Kuznets Curve (EKC) hypothesis for various types of carbon dioxide emissions (total, commercial, electrical, industrial, residential, and transportation CO_2) in the US from 1973 to 2015 using rolling window estimation. The results showed the inverted U-shaped EKC hypothesis is valid for total, industrial, electrical, and residential CO_2 emissions. Khan et al. (2020) examined the connection between energy consumption, carbon dioxide emissions, and economic growth in Pakistan from 1965 to 2015 using the ARDL bounds test. The study found that both economic growth and energy consumption drive up carbon dioxide emissions in the short term and long term. Olubusoye and Musa (2020) studied 43 African countries to determine the relationship between economic growth and carbon emissions. The results showed that in 79% of the countries, carbon emissions rise with economic growth while a negative relationship was found in 21% of the countries.

Osadume (2021) investigated the effect of economic growth on carbon emissions in six selected West African countries between 1980 and 2019. The study used panel econometric methods for statistical analysis and found evidence of a long-term relationship among the variables. The author also indicated that economic growth has a positive and significant influence on carbon dioxide emissions in the short run. In another study, Khobai and Sithole (2022) investigate the relationship between carbon emissions and economic growth in South Africa from 1984 to 2018, using ARDL bounds and VECM techniques. They found a long relationship and bidirectional causality between economic growth and carbon emissions.

Regarding the relationship between carbon emissions and energy consumption, Soytas et al. (2007) found that there is no long-run causality between income and carbon emissions in the United States, but it is found that energy consumption has an impact on carbon emissions. Halicioglu (2009) studied the relationship between carbon emissions, energy consumption, income growth, and foreign trade in Turkey between 1960 and 2005 using the bounds test method. The results revealed two forms of long-run relationships: Carbon emissions are influenced by energy consumption, foreign trade and income growth, while income is influenced by foreign trade, energy consumption and carbon emissions.

Pao and Tsai (2011) analyzed the dynamic relationship between energy consumption, economic growth, and carbon emissions in Brazil over a 27-year period (1980-2007). The study revealed an inverted U-shaped relationship between income and both environmental damage and energy consumption, meaning that these factors initially increase with income, reach a peak, and then decrease. The Granger causality test indicated that income, energy consumption, and emissions have a reciprocal influence on each other. Li et al. (2017) investigated the correlation between CO_2 emissions, economic growth, and the consumption of three types of fossil fuels (coal, gas, and oil) in China from 1965 to 2015. The Johansen cointegration test revealed a long-term relationship between the variables. The VECM showed a two-way relationship between coal consumption and CO_2 emissions, and between GDP and gas consumption. There was also a one-way relationship between GDP and oil consumption to CO_2 emissions and from GDP to oil consumption.

Mathieu et al. (2019) studied the relationship between energy consumption, carbon emissions, and economic growth in Togo. They used the ARDL model and found a long-term relationship among the variables. Osobajo et al. (2020) examined the impact of energy consumption and economic growth on CO_2 emissions in 70 countries from 1994 to 2013. The pooled OLS and fixed methods demonstrated a long-term relationship and positive effects on carbon emissions. Fong et al. (2022) studied the link between energy consumption and CO_2 emissions in 11 cities in the Guangdong-Hong Kong-Macao area between 2010 and 2016. They found that the average efficiency of the cities was 0.708, with only Macao SAR, Shenzhen, and Hong Kong SAR achieving full efficiency of 1 throughout the study period.

3. METHODOLOGY AND DATA

Our study uses ARDL econometric method, introduced by Pesaran et al. (2001), to examine long and short-term variable relationships with different orders of integration. ARDL has three benefits over prior cointegration methods: (1) it can handle variables with different orders of integration (I [1] or I [0]) it's more efficient for small data sets, and (2) it provides accurate long-term model estimates (Harris and Solis, 2003). To determine the optimal lag number (p, q) of our model, we will use the information criteria of Akaike-AIC, Schwarz-SIC, and Hannan-Quin. Our proposed model is based on the broader literature on the nexus between carbon emission and economic growth, especially the work of Khobai and Sithole (2022). Our ARDL specification takes the following form:

$$\begin{aligned}\Delta L\_CO2_t = a_0 + \sum_{i=1}^{p} a_{1i}\Delta L\_CO2_{t-i} + \sum_{i=0}^{q} a_{2i}\Delta L\_EN_{t-i} \\ + \sum_{i=0}^{q} a_{3i}\Delta L\_RGDP_{t-i} + \sum_{i=0}^{q} a_{4i}\Delta L\_FDI_{t-i} + \\ \sum_{i=0}^{q} a_{5i}\Delta L\_POP\_G_{t-i} + \sum_{i=0}^{q} a_{6i}\Delta L\_POP\_URB_{t-i} \\ + b_1 L\_CO2_{t-i} + b_2 L\_EN_{t-i} + b_3 L\_RGDP_{t-i} + \\ b_4 L\_FDI_{t-i} + b_5 l\_POP\_G_{t-i} \\ + b_6 L\_POP\_URB_{t-i} + \varepsilon_t\end{aligned}$$

With Δ the first difference operator; a_0 constant; $a_1 \ldots a_6$ represent short-term effects; $b_1 \ldots b_6$ relate to the long-term dynamics of the model; ε_t is the error term (white noise).

Table 1 illustrates the description of data covering the period from 1990 to 2021 for Morocco. The data for the analysis were collected from the World Bank Development indicators. Our choice of variables is based on previous empirical work on the subject while taking into account other essential control variables whose influence affects carbon emissions (Shahbaz et al., 2011; Ozturk and Acaracvi, 2013; Boutabba, 2014; Khobai and Sithole, 2022). All variables are transformed into logarithms. This transformation has several advantages. On the one hand, it facilitates the interpretation of the estimated coefficients which are interpreted as elasticity. On the other hand, the logarithm helps to control the heteroscedasticity problem. Moreover, the use of the logarithm allows the smoothing of variables that are characterized by differences in their units of measurement.

4. RESULTS

This section examines the short and long-term relationship between economic growth and carbon emissions in Morocco using the ARDL bounds test approach. We will apply a specific approach that focuses on the study of the stationarity of the series, the cointegration test with bounds, and the estimation of the short and long-term dynamics.

4.1. Unit Root Tests

Unit root tests are used to determine the order of integration of variables. These tests include the well-known ADF (Dickey and Fuller), PP (Phillips and Perron), and KPSS (Kwiatkowski-Phillips-

Table 1: Variables description

Variables	Definition
L_ CO_2	Carbon dioxide emissions, metric tons per capita
L_EN	Energy use (kg of oil equivalent) per $1,000 GDP (constant 2011 PPP)
L_RGDP	GDP per capita (PPP, constant 2017 international $)
L_FDI	Foreign direct investment, net inflows (% of GDP)
L_POP_G	Population growth (annual %)
L_POP_URB	Urban population (% of the total population)

Source: World development Indicators (WDI), World Bank

Schmidt-Shin). The ARDL approach accommodates variables that are stationary in level, first difference, or a combination of both.

Table 2 presents the results of the ADF, PP, and KPSS unit root tests performed on the levels and first difference of the variables. The tests are conducted assuming that the series under study has a unit root and are compared to the alternative hypothesis that the series does not have a unit root. Table 2 shows that all the variables are non-stationary in levels but become stationary at the first difference, except for the variables L_RGDP and L_FDI which are stationary in levels. Our variables display different orders of integration (I (0) and I (1)), which justifies the use of the Autoregressive Distribute Laged (ARDL) model. Then, the variables show different orders of integration, which leads us to look at whether there is a cointegration relationship.

4.2. Co-Integration Bound Test and Optimal Lag

To estimate the short and long-term dynamics, it's necessary to conduct the cointegration test at the bounds as well as the optimal lags for all variables. The ARDL model uses Fisher's F-value as a test statistic and compares it to critical values to determine if there is a cointegrating relationship between the variables. The results of the cointegration test show that a cointegrating relationship exists, as the F-stat value (8.5426) is higher than both bounds at a 5% significance level (Table 3). This indicates that there is a long-term relationship between the variables being analyzed.

To select the most appropriate ARDL model, it's necessary to determine the specification that maximizes the information criteria. In other words, we need to select the optimal lag number. To do this, we will use the Schwarz Information Criterion (SIC) to select the optimal ARDL model. Figure 1 presents the results for the selection order criteria and indicates that an ARDL (3, 0, 1, 2, 02, 0) among the 19 others presented, is the more appropriate because it offers the smallest values of (AIC).

4.3. Long-run and Short-run Dynamics

The long-term dynamics results indicate a positive correlation between economic growth and carbon emissions, which is statistically significant at the 5% significance level (Table 4). More specifically, the elasticity of economic growth reveals that a 1% increase in the latter generates an average increase of 4.01% in carbon emissions, given that the other factors remain constant. At the same time, the effect of the square of real GDP per capita is negative and significant at the 5% significance level. A 1% increase in real GDP per capita leads to a decrease in carbon emissions of 0.24%. Moreover, the results indicate that population growth and urban population have a positive and statistically significant impact on long-term carbon emissions. This evidence supports the conclusions of Apergis and Payne (2009) and Awad and Abugamos (2017).

The results in Table 5 show a positive and significant correlation between real GDP per capita and carbon emissions in the short term. Furthermore, the findings reveal a negative and statistically significant relationship between carbon emissions and the square of real GDP per capita, indicating the validity of the EKC in the short term for Morocco, which is supported by Aslan et al. (2018) and Cetin et al. (2018). The results also indicate a significant and positive relationship between carbon emissions and energy consumption, with a 1% increase in energy consumption resulting in a 0.24% increase in carbon emissions, consistent with the research conducted by Soytas et al. (2007). Additionally, the

Figure 1: Selection of optimal lag

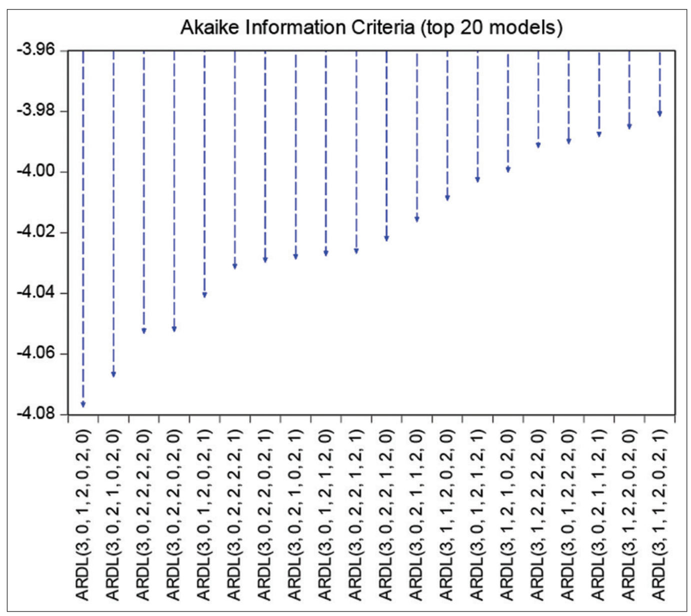


Table 2: The results of the ADF, PP, and KPSS test

Variables	Levels			First difference			Decision
	ADF	PP	KPSS	ADF	PP	KPSS	
L_ CO_2	−0.3939	−0.1883	0.7526	−6.9953***	−9.0732***	0.2226**	I (1)
	(−2.9604)	(−2.9604)	(0.4630)	(−2.9639)	(−2.9639)	(0.4630)	
L_EN	0.029974	0.551808	0.7475	−5.3131**	−7.2247**	0.1747**	I (1)
	(−2.960411)	(−2.960411)	(0.4630)	(−2.9678)	(−2.9639)	(0.4630)	
L_RGDP	−7.8989**	−7.8913**	0.6238**	-	-	-	I (0)
	(−2.9604)	(−2.9604)	(0.7390)				
L_FDI	−5.824293**	−5.8141**	0.2916**	-	-	-	I (0)
	(−2.960411)	(−2.9604)	(0.4630)				
L_POP_G	−1.5022	−1.704202	0.6453	−3.0817*	−2.9588*	0.2066**	I (1)
	(−2.9639)	(−2.960411)	(0.4630)	(−2.9639)	(−2.9639)	(0.4630)	
L_POP_URB	1.143055	0.2053	0.7539	−4.2939***	−4.2939***	0.1352***	I (1)
	(−2.963972)	(−2.9604)	(0.4630)	(−2.9678)	(−2.9678)	(0.7390)	

Source: Authors calculation. Note: Significant at ***1%, **5% and *10%. PP: Phillips and perron, KPSS: Kwiatkowski-phillips-schmidt-shin coefficient of the lagged error term (ECTt-1) is negative and statistically significant (−1.73), which suggests that there is a long-term relationship among carbon emissions, economic growth, energy consumption, foreign direct investments, population growth, and urban population.

4.4. Causality Tests of Toda-Yamamoto

The Granger test is a traditional method for testing causality, but it has limitations. One major limitation is that it only applies to stationary series, which means that it cannot effectively handle variables that are integrated at different orders. To address this issue, the Toda-Yamamoto (1995) causality test is used. The Toda-Yamamoto causality test is based on Wald's statistic "W," which follows a Chi-square distribution. The null hypothesis for this test is that there is no causality between the variables being analyzed, with a probability threshold of 5%. Using Wald's statistic "W," provides a reliable and statistically significant test for causality, helping researchers to better understand the complex relationships between variables.

Table 3: F-statistic bound test

F-bounds test		Null hypothesis: No levels of relationship		
Test statistic	Value	Signif.	I (0)	I (1)
F-statistic k	8.542649	(%)	Asymptotic: n=1000	
		10	1.99	2.94
		5	2.27	3.28
		1	2.88	3.99

Source: Authors' calculation using Eviews 10

Table 4: Long-run coefficients results of the ARDL model

Variable	Coefficient	Std. error	t-statistic
L_EN	0.0013	0.0004	3.2527
L_RGDP	4.0178	1.7173	2.3396
L_RGDP^2	−0.2447	0.0977	−2.5029
L_FDI	0.0001	0.0027	0.0451
L_POP_G	0.1195	0.0520	2.2982
L_POP_URB	3.1650	0.5597	5.6548
C	−28.6504	7.6879	−3.7267

Source: Authors' calculation using Eviews 10. ARDL: Autoregressive distribute laged

Table 5: Short run coefficients results of the ARDL model

Variable	Coefficient	Std. error	t-statistic
D (CO_2 [−1])	1.1129	0.1390	8.0036
D (CO_2 [−2])	0.9096	0.1152	7.8988
D (L_EN)	0.248	0.1263	1.9636
D (L_RGDP)	−4.6947	2.6134	−1.7964
D (L_RGDP^2)	0.3025	0.1524	1.9842
D (L_FDI)	0.5111	0.1527	3.3471
D (POP_G)	0.4469	0.1515	2.9500
D (POP_URB)	0.8438	0.1434	5.8825
CointEq (−1)*	−1.7332	0.171187	−10.1248

Source: Authors' calculation using Eviews 10. ARDL: Autoregressive distribute laged

The results of the causality test within the meaning of Toda-Yamamoto are presented in Table 6. These results suggest a bidirectional causality between population growth and energy consumption. This means that population growth can have an impact on energy use since a larger population requires more energy resources to meet its needs. Conversely, energy consumption can also influence population growth by improving living and health conditions, leading to an increase in birth rates.

However, there are also unidirectional causal relationships between the variables. For example, GDP per capita may be caused by foreign direct investment (FDI) and population growth since these factors can stimulate economic activity and increase income. Additionally, energy consumption can be caused by GDP per capita since a more advanced economy requires more energy resources to support its production and consumption. Finally, population growth may also be caused by GDP per capita since a stronger economy can offer more employment opportunities and better living conditions, leading to an increase in population.

4.5. Robustness Tests

To assess the robustness and validity of our long and short-run relationship, we conduct diagnostic tests and CUSUM and CUSUM Square stability tests. The diagnostic tests include the Breusch-Godfrey LM test for serial dependence, the Breusch-Pagan-Godfrey test for heteroskedasticity, and the Jarque-Bera test for error normality. Table 7 indicates that the error terms in the short-run models don't exhibit serial correlation, are free from heteroskedasticity, and are normally distributed. The results confirm that the short-run models are valid.

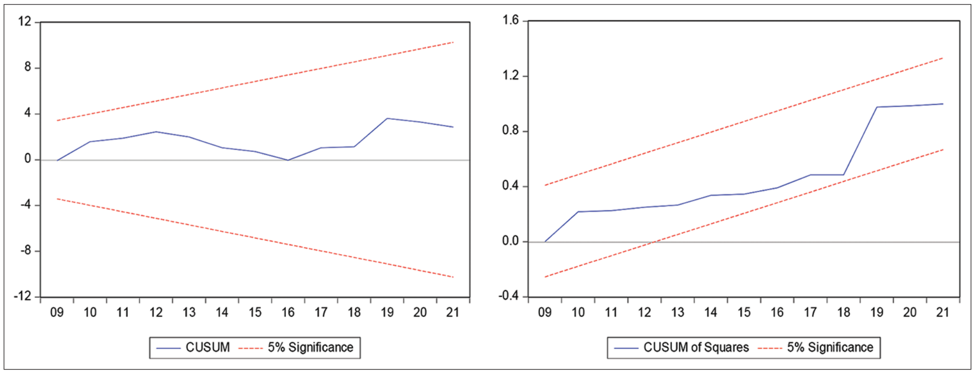
The stability of the long-run parameters was tested using CUSUM and CUSUM of recursive squares. The results, shown in Figure 2, indicate that the selected ARDL model is stable because the recursive residuals remain within the confidence interval at the 5% threshold at all times. In the same sense, the CUSUM Square test shows that the cumulative sum of squares of the recursive residuals always remains within the interval for the 5% confidence level, which suggests that the residual variance is stable. In sum, our different tests confirm the good specification of our model and that all coefficients are stable over the period studied.

Table 6: Causality tests of toda-yamamoto

Variables	L_CO_2	L_EN	L_RGDP	L_FDI	L_POP_G	L_POP_URB
L_CO_2	-	2.7324 (0.2551)	4.8668 (0.0877)	0.2006 (0.9046)	7.9395** (0.0189)	1.2469 (0.5361)
L_EN	0.2683 (0.8745)	-	0.6330 (0.7287)	1.4522 (0.4838)	4.6115* (0.0997)	0.8221 (0.6630)
L_RGDP	1.5917 (0.4512)	10.9253*** (0.0042)	-	1.3204 (0.5168)	0.3278 (0.8488)	7.9698** (0.0186)
L_FDI	1.0609 (0.5883)	4.3744 (0.1122)	8.7705** (0.0125)	-	4.2693 (0.1183)	0.0468 (0.9769)
L_POP_G	4.4889 (0.1060)	10.8992** (0.0043)	8.4952** (0.0143)	0.0665 (0.9673)	-	0.3008 (0.8604)
L_POP_URB	1.7157 (0.4241)	4.5146 (0.1046)	3.5037 (0.1735)	0.6834 (0.7106)	4.5383 (0.1034)	-

Source: Authors' calculation using Eviews 10. Note: Significant at ***1%, **5% and *10%

Figure 2: CUSUM and CUSUM square stability test



Source: Authors' calculation using Eviews 10

Table 7: Short-run diagnostics

Test	F-statistics	Prob.
Normality (Jarque-Bera test)	0.1935	0.9077
Heteroskedasticity (Breusch-Pagan-Godfrey test)	1.1835	0.3785
Serial correlation (Breusch-Godfrey Serial Correlation LM test)	0.9106	0.4284

Source: Authors calculation Eviews 10

5. DISCUSSION AND CONCLUSION

The main purpose of the study was to investigate the short and long-term relationship between carbon emissions, economic growth, and energy consumption in Morocco from 1990 to 2021 using the autoregressive lag model (ARDL) approach. The findings showed that there is a long-term relationship between economic growth and carbon emissions in Morocco. The results further indicated that both in the long and short term, the impact of economic growth (represented by GDP) on carbon emissions is positive and significant. Meanwhile, the impact of the square of GDP (GDP2) on carbon emissions is significant and negative in both the long and short term. This relationship is consistent with the Environmental Kuznets Curve (EKC) hypothesis, which suggests that as the economy grows, environmental degradation initially increases but then decreases as income levels continue to rise. This finding is consistent with the findings of Berahab (2017) and Bensbahou and Seyagh (2020) for Morocco, as well as the studies conducted by Pao and Tsai (2011) and Khobai and Sithole (2022) in other countries.

Furthermore, the short-term results indicate a positive and significant correlation between real GDP per capita and carbon emissions, but a negative and statistically significant relationship between carbon emissions and the square of real GDP per capita, supporting the EKC hypothesis in the short term. This finding is consistent with the studies conducted by Aslan et al. (2018) and Cetin et al. (2018). Finally, the results also indicate a positive and significant relationship between carbon emissions and energy consumption, consistent with the findings of Soytas et al. (2007).

The study also found that energy consumption has a positive impact on carbon emissions in both the long and short term. This highlights the need for Morocco to prioritize alternative energy sources and energy efficiency to address its energy and environmental issues. The results showed that population growth and urban population have a positive impact on carbon emissions in the short term but a negative impact in the long term. Additionally, the findings indicated that foreign direct investment has a non-significant impact on carbon emissions in the short term and the long term. These results have significant implications for energy and environmental policies in Morocco.

In conclusion, the findings have important implications for policymakers in Morocco who must balance economic growth with environmental sustainability. The study's results suggest that Morocco should increase investment in renewable energy sources such as solar, wind, and hydro to reduce its carbon emissions and achieve energy sustainability. Additionally, implementing policies to encourage clean energy adoption and investment can further support this transition. Morocco has strong potential for solar and wind power, and utilizing these resources can help the country move towards a more sustainable energy mix.

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