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Nexus of Agricultural Economic Growth, Renewable Energy Supply, Trade Openness and CO2 Emissions in Morocco

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ABSTRACT

The Environmental Kuznets Curve posits that as economies develop, environmental pressures initially increase but subsequently decrease as incomes rise and societies adopt stricter environmental policies. This study explores the impact of CO2 emissions, renewable energy consumption, employment in the agricultural sector, and trade openness on agricultural GDP in Morocco. We utilized annual data from 1990 to 2022 and employed the ARDL approach to analyze these long-term relationships. Our findings indicate that CO2 emissions have a significant negative impact on agricultural GDP. Similarly, renewable energy consumption is associated with a decrease in agricultural GDP. Conversely, employment in the agricultural sector did not show a significant effect on agricultural GDP. Lastly, trade openness has a significant positive impact on agricultural GDP. These conclusions underscore the importance of policies aimed at reducing CO2 emissions, optimizing the use of renewable energies, and promoting trade to foster sustainable growth in Morocco's agricultural sector.

1. INTRODUCTION

Energy has always been a cornerstone of human development, driving both everyday life and economic progress. Despite advances in technology and shifts in energy systems, fossil fuels remain the dominant energy source worldwide. This dependence fuels rising global demand and has contributed significantly to increasing CO_2 emissions, making climate change one of the most pressing challenges of our time. Agriculture, as both a major consumer of energy and a sector highly vulnerable to environmental degradation, sits at the heart of this nexus. In emerging economies such as Morocco, agriculture plays a central role in ensuring food security, supporting rural livelihoods, and contributing to GDP. At the same time, the sector remains heavily exposed to climate variability and dependent on energy inputs, highlighting the importance of aligning agricultural growth with sustainable energy strategies.

In Morocco, energy is the cornerstone of economic development and modernization, particularly within the agricultural sector. The country relies heavily on imported fossil fuels—nearly 90% of its primary energy consumption in 2022—making it vulnerable to geopolitical disruptions and price volatility. To strengthen energy security and reduce carbon dependency, Morocco has committed to generating over half of its electricity from renewables by 2030, targeting approximately 20% each from solar and wind, and 12% from hydropower. As of 2019, renewables accounted for just under 20% of electricity generation—comprising wind (≈11.6%), solar (≈4%), and hydro (≈3.2%)—while fossil fuels still dominated the mix. Major projects like the Noor Ouarzazate solar complex (~582 MW) and expansive wind farms (e.g. Tarfaya, Midelt) exemplify Morocco's rapid scaling-up of renewable capacity.

While a substantial body of literature has examined the bilateral relationships between energy consumption and economic growth, and between energy use and environmental degradation, fewer studies have analyzed these dimensions within a single integrated framework. In particular, the role of renewable energy in shaping the link between agricultural economic growth and CO_2 emissions remains underexplored. Much of the existing evidence is concentrated in industrialized nations or at an aggregated macroeconomic level, with limited insights into sector-specific contexts such as agriculture. For Morocco and other MENA countries, where agriculture is a vital economic pillar and renewable energy investments are rapidly expanding, this gap is especially relevant.

This paper aims to investigate the causal nexus between agricultural economic growth, renewable energy supply, and CO_2 emissions, with a specific focus on Morocco as a
case study. The central objectives are:

1. To assess the long-term and short-term relationships between agricultural output, renewable energy consumption, and CO_2 emissions.
2. To evaluate whether renewable energy supply mitigates the environmental impact of agricultural economic growth.

This research is both timely and relevant. For Morocco, which is committed to expanding renewable energy capacity and modernizing its agricultural sector under the Green Morocco Plan and subsequent strategies, understanding these interactions is critical. By focusing on the agricultural sector, the study adds originality to the literature, as most prior research has examined aggregated national indicators.

Methodologically, the paper applies modern econometric techniques that allow for testing causal relationships, offering robust evidence for policymakers.

The remainder of the paper is organized as follows. Section 2 reviews the theoretical and empirical literature on the linkages between energy, agriculture, and the environment. Section 3 presents the data, variables, and econometric methodology. Section 4 reports and discusses the empirical findings. Section 5 concludes with key insights, highlighting contributions, limitations, and directions for future research.

2. LITERATURE REVIEW

The nexus in this study will be analyzed through the Environmental Kuznets Curve (EKC) framework, which outlines four possible testable hypotheses: the feedback, conservation, growth, and neutrality hypotheses. According to this framework, the relationship between economic growth and environmental quality can take different forms depending on the stage of development. Originating from the work of Grossman and Krueger (1991), the EKC suggests that environmental degradation tends to rise during the early stages of economic growth but declines in the long run as economies mature. The decline is explained by the increased availability of resources and technological progress, which can be redirected toward environmental improvements. This makes the EKC framework particularly useful for examining the interaction between pollution, climate variability, and agricultural economic growth. In addition, the study explores the nexus between economic growth and renewable energy consumption. It is hypothesized that climate change negatively affects agricultural performance, as extreme weather patterns—such as excessive rainfall, floods, and droughts—reduce productivity. This dynamic can also be interpreted through the treadmill theory, which examines how macroeconomic drivers such as natural resource consumption, technological innovation, finance, and human capital shape growth patterns (Jahanger et al., 2023). The focus here is on natural resource use, with particular emphasis on energy. Data from the International Energy Agency (IEA) shows that global energy consumption has increased at nearly twice the average annual pace observed since 2010, underlining the urgency of understanding the implications of renewable energy adoption for sustainable agricultural growth. A notable study by Fotio et al. (2022) examined renewable energy's sectoral impact on value-added in 12 SSA countries, 1985–2017. Using a PMG–ARDL approach, they found renewable energy has a significant positive long-run effect on agricultural value-added (as well as on industry and services), indicating that expanding renewable energy usage ultimately improves agricultural economic performance. No significant short-run effect was detected, suggesting a time lag before benefits materialize. Their causality tests further revealed a unidirectional causality from renewable energy to agricultural output, with no reverse causality observed. Chopra et al. (2022) analyzed ten ASEAN countries (using MG estimators) with a focus on sustainability. They report that CO_2 emissions (environmental degradation) significantly reduce agricultural productivity in the region, while renewable energy consumption contributes positively to agricultural output. Notably, they include deforestation and natural resource indicators in their model – finding that loss of forest cover and high natural resource dependence also negatively affect agriculture. This suggests that unsustainable practices and emissions in ASEAN undermine farm productivity, whereas shifting to renewables supports sustainable growth. Interestingly, despite ASEAN's strong economic integration, regional trade integration was found to not significantly boost agricultural productivity in this study. Causality tests in Chopra et al. confirmed bidirectional causality between renewable energy use and agricultural productivity – meaning greater renewable uptake and agricultural growth reinforce each other over time.

Several multicountry studies in the 2020s reinforce these themes. For instance, Akram et al. (2021) applied panel quantile regression to BRICS economies and found heterogeneous effects of renewables on growth (with weaker or negative impacts in lower-growth quantiles). Their findings contributed to the literature cited by Tagwi (2023) indicating that in some developing contexts, renewable energy expansion has not yet translated into higher growth. Meanwhile, global analyses (e.g. Magazzino et al. 2022) similarly report mixed results, with some panels showing renewable energy's growth benefits only manifest in the long run or under certain conditions.

Tagwi (2023) provides an in-depth case study of South Africa's agricultural sector from 1990–2021. Using an ARDL bounds test approach, Tagwi found a negative long-run relationship between renewable energy supply and agricultural GDP in South Africa. In fact, an increase in the scale of renewable energy was associated with a slowdown in agricultural economic growth.

In Pakistan, researchers found that agricultural expansion led to higher CO_2 emissions and warned of environmental constraints (Yasmeen et al. 2022), while Turkey has documented periods where renewable energy had an insignificant or even growthdampening effect until reaching sufficient scale (Ozturk et al. 2022). A dynamic ARDL analysis in Iran (Karimi et al. 2021) even suggests nonlinear effects, where the impact of renewable energy on growth can switch signs under different regimes of emissions or energy intensity. These country studies reinforce that the agriculture-energyemissions nexus is highly context-dependent. Factors like the country's energy mix, stage of renewable adoption, regulatory support, and vulnerability to climate impacts all mediate how renewable energy and CO_2 emissions ultimately influence agricultural economic output.

Empirical evidence since 2020 offers a nuanced picture of how renewable energy affects agricultural economic performance in developing countries. On one hand, several studies demonstrate a positive linkage – especially in the long run or in multicountry analyses. The rationale is that renewable energy (solar irrigation pumps, bioenergy, wind power for farms, etc.) can lower energy costs and make agriculture more sustainable, thus raising productivity. The ASEAN panel study showed clear benefits of renewables for agriculture, with renewable consumption significantly increasing agricultural productivity across countries. Similarly, the SSA sectoral analysis found that investments in renewables improved agricultural value-added given enough time to materialize. These positive effects are often statistically significant and align with sustainable development goals – indicating that as renewables become more prevalent and affordable, they can be a driver of agricultural growth. Causality tests even suggest that greater renewable energy use can lead to growth in agriculture (unidirectional causality in SSA), and concurrently growing agriculture can feedback into higher renewable adoption (bidirectional causality in ASEAN).

On the other hand, evidence from individual countries in the short-to-medium term reveals challenges. In both South Africa and Morocco, the coefficient on renewable energy supply/consumption was negative in long-run ARDL estimations. These findings were statistically significant (at conventional levels) and suggest that at current scales, renewable energy has not been a growth engine for the agricultural sector – it may even be a slight drag. The likely explanation, as authors point out, is that renewable infrastructure in agriculture is still nascent in many developing countries. Initial adoption of renewables can incur high costs (solar panels, biogas digesters, etc.), and intermittent supply can disrupt traditional practices. If farmers face higher energy costs or unreliable power during the transition, agricultural output could suffer temporarily. Thus, the sign of the renewable–growth relationship appears to depend on a country's progress in the energy transition. In contexts where renewables are <fully scaled or efficient, studies find either insignificant or negative impacts on agricultural GDP. By contrast, once renewables achieve greater penetration and cost parity, the relationship tends to turn positive (as seen in multi-country averages and higher-income developing states). Policy implications from this are clear: to harness renewables for agricultural growth, governments must invest in making renewable technology affordable and reliable for farmers. Supportive measures (subsidies, credit, technical training) can help shift the nexus from a short-run tradeoff to a long-run win-win.

The role of CO_2 and other greenhouse emissions in agricultural economic growth is complex. Most studies find that agricultural output and CO_2 emissions are positively correlated in recent historical data. As agriculture expands (through mechanization, fertilizer use, land-use change), emissions inevitably rise – a relationship confirmed in South Africa, Morocco, and many panel studies. Tagwi (2023) notes this positive elasticity was "expected a priori" since it reflects the classic growth-emissions tradeoff described by the Environmental Kuznets Curve. Indeed, numerous authors have documented that increases in agricultural GDP tend to be accompanied by higher CO_2 output in the development phase (e.g. Rehman et al. 2019; Eyuboglu & Uzar 2020; Yasmeen et al. 2022). This does not mean CO_2 is beneficial to agriculture, but rather that historically, more intensive agriculture has involved practices that emit more carbon. In the short run, some studies even find bidirectional positive effects – Lamharher et al. (2025) observed that shocks to CO_2 emissions were associated with short-run increases in agricultural GDP, and vice versa. This likely captures the fact that when farms use more energy (causing more emissions), they can temporarily produce more.

However, other research highlights the damaging impact of CO_2 emissions and climate change on agriculture, especially in the long term. In the ASEAN study, higher CO_2 levels (as a proxy for environmental degradation) significantly lowered agricultural productivity. This suggests that beyond a certain threshold, the negative externalities – such as climate change-induced weather extremes, temperature stress, and ecological degradation – start to outweigh the short-term productivity gains from emissionsintensive agriculture. Morocco's findings also implicitly acknowledge this concern: while their regression shows a positive association, the authors stress that policies to reduce CO_2 are critical for sustainable agricultural growth. In other words, if emissions continue unchecked, the resulting climate impacts (droughts, heatwaves, etc.) will ultimately hurt agricultural output. We are already seeing early evidence of this: for instance, Holka et al. (2022) note that global warming from agricultural GHGs is adversely affecting yields and farm incomes, and efforts like organic farming can mitigate agriculture's carbon footprint. Thus, the literature implies an important temporal distinction: in the past and present, CO_2 emissions rise with agricultural growth; but going forward, high emissions will increasingly constrain agricultural growth. This underscores the need for climate adaptation in the agricultural sector of developing countries. By adopting cleaner energy and climate-smart practices, the sector can decouple growth from emissions – avoiding the severe long-run penalties of climate change.

3. METHODOLOGY

3.1. Model specification

The model specification aims to establish the functional relationships between the various variables of interest in the study: agricultural economic growth, CO_2 emissions, renewable energy, trade openness, and employment in the agricultural sector. The proposed model can be formulated as a multiple regression equation, where agricultural economic growth is the dependent variable and the other variables are the explanatory variables. Mathematically, the model can be expressed as follows:

$$EconomicGrowth = \beta_0 + \beta_1 Emissions\ of\ CO2 + \beta_2 Renewable\ Energy$$
$$+\beta_3 TradeOpenness + \beta_4 Agri\_Employment + \epsilon$$

Where:

- β_0 is the intercept,
- β_1, β_2, β_3, β_4 are the regression coefficients representing the marginal impact of each explanatory variable on agricultural economic growth, and
- ε is the error term.

This specification allows for quantifying the individual effect of each factor while controlling for the others, thereby offering a better understanding of the complex dynamics between agricultural growth and environmental and economic influences. The use of stationarity tests and cointegration techniques is crucial to ensure that the coefficient estimates are reliable and that the observed relationships are not spurious.

3.2. Data and Sources

This section presents the data that will be used in the impact study on the relationship between agricultural economic growth, CO_2 emissions, and renewable energy. The study uses annual data covering the period from 1990 to 2022. The methodology includes time series stationarity tests and cointegration techniques to avoid misleading results.

Table 1: Data sources and period

Variable	Period	Source
Agricultural GDP	1990–2022	World Bank
CO_2 Emissions	1990–2022	World Bank
Employment in the Agricultural Sector	1990–2022	World Bank
Renewable Energy Supply	1990–2022	International Energy Agency
Trade Openness (% of GDP)	1990–2022	World Bank

The study is based on annual data collected over a 32-year period from 1990 to 2022. These data include five key variables:

- Agricultural Economic Growth: Measured by the agricultural value added as a percentage of GDP. This data is obtained from the World Bank economic databases.
- CO_2 Emissions: Measured in metric tons per capita or per unit of GDP. Common sources for this data include the CO_2 emissions database of the International Energy Agency (IEA) and countries' environmental reports.
- Renewable Energy: Measured as a percentage of total energy consumption or in terms of energy production (e.g., megawatts of renewable energy produced). The data were obtained from the IEA.
- Trade Openness: Measured by the ratio of agricultural exports and imports relative to agricultural GDP. These data help assess the impact of trade on the agricultural sector. In this study, the variable was calculated using World Bank data.
- Employment in the Agricultural Sector: Measured as the percentage of the labor force employed in agriculture. These data are essential to evaluate the impact of agricultural growth and energy policies on rural employment. The source is the World Bank.

4. RESULTS

4.1. Unit root test

Examining the properties of time series before analyzing relationships between variables is crucial due to the challenges posed by non-stationary series in regression analysis. It is well established in the literature that an Ordinary Least Squares (OLS) regression can yield spurious results when data contain a unit root, except in the case of cointegration (Hamilton, 1994). Therefore, insufficient investigation into the presence of a unit root may lead to seemingly significant but actually meaningless or, at best, inaccurate estimates.

To avoid such spurious estimation, stationarity properties are verified using unit root tests, notably the Augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1979) and the Phillips-Perron (PP) test (Phillips & Perron, 1988).

Tests of Variables at Level

The table provides the results of the Augmented Dickey-Fuller (ADF) and PhillipsPerron (PP) unit root tests to assess the stationarity of the time series of the variables Log (Agri_PIB), Log(CO2), Log(EMP), Log(Energie), and Log(Trade) at level. The tStatistic values indicate the strength of the test, while the P-value values determine the statistical significance of the test. The decisions are categorized as the process being considered a TS (Trend Stationary) process or a DS (Differency Stationary) process.

For the variable Log(Agri_PIB), the ADF and PP tests show a significance level below 5%, indicating that the series is stationary. The analysis of the test results indicates that the trend component of the test is significant, indicating that the series is stationary around its trend. Therefore, Log(Agri_PIB) is a non-stationary process of type TS. For the variables Log(CO2), Log(EMP), Log(Energie), and Log(Trade), the ADF and PP tests reveal significance thresholds below 5%, indicating non-stationarity for these time series.

Table 2: Stationarity results for variables at level

Variables	ADF t- Statistic	ADF P- value	PP t- Statistic	PP P- value	Decision
Log(Agri_PIB)	-6.307141	0.0001	-6.33144	0.0001	TS
Log(CO2)	-2.412254	0.1467	-2.81983	0.0667	DS
Log(EMP)	2.407614	0.9999	2.095776	0.9998	DS
Log(Energie)	-2.588303	0.2877	-2.63056	0.2704	DS
Log(Trade)	-3.164396	0.1095	-3.01191	0.1447	DS

Tests of Variables: First Difference

The table presents the results of the Augmented Dickey-Fuller (ADF) and PhillipsPerron (PP) unit root tests to assess the stationarity of the time series of the variables Log(Agri_PIB), Log(CO2), Log(EMP), Log(Energie), and Log(Trade) at first difference. The t-Statistic values represent the strength of the test, while the P-value values indicate the statistical significance of the test. The order of integration indicates the number of differences needed to make the time series stationary.

For the variable Log(Agri_PIB), the trend component was removed from the original series and the ADF and PP tests show high t-Statistics and very low P-values (0.000), leading to the decision that the time series is stationary.

For the variables Log(CO2), Log(EMP), Log(Energie), and Log(Trade), the ADF and PP tests reveal high t-Statistics and very low P-values (0.000), indicating that these time series are stationary. The order of integration for these variables is also I(1), suggesting that one difference is necessary to reach stationarity.

Table 3: Stationarity results for first difference

Variables	ADF t-Statistic	ADF P- value	PP t-Statistic	PP P-value	Decision	Order of Integration
Log(Agri_PIB)	-6.307141	0.000	-6.33144	0.000	TS	I(1)
Log(CO2)	-9.10811	0.000	-10.7948	0.000	DS	I(1)
Log(EMP)	-4.654867	0.004	-4.57102	0.005	DS	I(1)
Log(Energie)	-5.281031	0.001	-5.84139	0.000	DS	I(1)
Log(Trade)	-4.243062	0.011	-5.86179	0.000	DS	I(1)

F-Bound Test

In the absence of I(2) higher-order variables in the equation, the model examines whether a long-term relationship exists between the variables using the OLS technique, followed by a Wald test in Eviews 12.

Table 4: F-bound test results

Test Statistic	Value	Significance	I(0)	I(1)
F-statistic	26.86	10%	2.20	3.09
k = 4		5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37

The calculated F-statistic is 26.86, which is higher than the upper critical value of 4.37 at the 1% level. Thus, the null hypothesis of no cointegration is rejected, implying longterm cointegration relationships between the variables. This means there is a long-run relationship between AGRI_PIB, CO2, EMP, ENERGIE, and TRADE over the period 1990 to 2022 in Morocco.

Estimation Results

Long-Term Relationship Analysis

The following table provides a detailed analysis of the regression coefficients for each explanatory variable in relation to agricultural GDP, measured by the logarithm of agricultural GDP.

Firstly, the negative coefficient of LOGCO2 (-0.81) with a p-value below 5% suggests a significant inverse relationship between CO_2 emissions and agricultural GDP. This indicates that CO_2 emissions have a negative impact on agricultural GDP over time. Indeed, a 1% increase in CO_2 emissions would result in a 0.81% decrease in agricultural output.

In contrast, the coefficient of LOGEMP is 0.136, but with a p-value of 0.3416, which is not statistically significant. This suggests that employment does not have a significant long-term impact on agricultural GDP in the model considered.

Regarding renewable energy consumption (LOGENERGIE), its coefficient is negative (-0.40) with a p-value below 5% (0.000), indicating a significant negative relationship between energy consumption and agricultural GDP. A decrease in energy consumption is associated with an increase in agricultural GDP.

LOGTRADE has a positive coefficient of 1.30 with a p-value below 5%, suggesting a significant positive relationship between trade and agricultural GDP. This implies that an increase in trade is associated with an increase in agricultural GDP. Indeed, Morocco has trade relations with European countries concerning agricultural products, which justifies the positive impact of trade openness on agricultural economic growth.

Table 5: Long run relationship estimates

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGCO2	-0.816161	0.159368	-5.121232	0.0002
LOGEMP	0.136774	0.138566	0.987072	0.3416
LOGENERGIE	-0.488774	0.165032	-2.961698	0.0110
LOGTRADE	1.389307	0.218927	6.345976	0.0000
C	3.552693	1.527026	2.326544	0.0368

Comparing these results with those reported by Tagwi Aluwani (2023), we find different relationships between the variables compared to our model's coefficients. In Aluwani's study, CO_2 emissions appear to have a positive impact on agricultural GDP, meaning that their increase is associated with an increase in GDP. In contrast, in our model, CO_2 emissions have a negative impact on agricultural GDP. Furthermore, the effect of foreign trade on agricultural GDP is positive in our study—this result is similar to that obtained by the same study. Lastly, renewable energy production appears to have a significantly negative effect on agricultural GDP in Aluwani's study, which is also consistent with the result obtained in this study, indicating that renewable energy consumption (LOGENERGIE) also has a negative effect.

Short-Term Relationship Analysis

The following table provides the results of the short-term analysis of the explanatory variables on the dependent variable. The coefficients of the first-difference variables (D) show significant relationships with the dependent variable.

More specifically, the positive coefficient of D(LOGCO2) suggests a significant positive relationship between changes in CO_2 emissions and agricultural GDP in the short term.

Similarly, the positive and significant coefficients of the energy consumption differences (from D(LOGENERGIE) to D (LOGENERGIE (-3))) indicate a positive relationship between these changes and the dependent variable.

In contrast, the coefficients of trade openness differences (D (LOGTRADE (-1)) to D(LOGTRADE (-2))) were significant, suggesting a significant negative effect of trade openness on agricultural GDP growth.

Moreover, the negative and significant coefficient of CointEq (-1) indicates the existence of short-term cointegration between the variables. This confirms that in the event of a short-term imbalance, the model will return to its long-term equilibrium at an adjustment speed of 173% annually.

In terms of model fit, the model appears well-fitted with an R^2 of 0.96, suggesting that the explanatory variables explain a large part of the variation in the dependent variable in the context of short-term analysis.

Table 6: Short run relationship results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D (LOGCO2)	0.612723	0.257268	2.381652	0.0332
D (LOGENERGIE)	0.220731	0.138638	1.592141	0.1354
D (LOGENERGIE (-1))	1.035552	0.163535	6.332298	0.0000
D (LOGENERGIE (-2))	1.379719	0.157531	8.758371	0.0000
D (LOGENERGIE (-3))	0.941452	0.145748	6.459464	0.0000
D(LOGTRADE)	0.146754	0.200607	0.731551	0.4774
D (LOGTRADE (-1))	-1.551997	0.219350	-7.075442	0.0000
D (LOGTRADE (-2))	-0.562390	0.157662	-3.567066	0.0034
CointEq (-1)*	-1.738110	0.116334	- 14.94064	0.0000
R-squared	0.959450			
Adjusted R^2	0.941428			
Durbin-Watson	1.833622			

Model validity

First, to detect whether the residuals are autocorrelated in the three regression models, the Breusch-Godfrey test was used. The null hypothesis of this test states that there is no autocorrelation in the residuals, while the alternative hypothesis assumes its presence. The null hypothesis is rejected if the computed value exceeds the critical value from the Fisher test or if the associated probability is less than 5%. According to the test results (F-statistic = 0.097195; Prob. F = 0.7606), the probability associated with the Breusch-Godfrey test exceeds 5%. Therefore, we cannot reject the null hypothesis, which means there is no evidence of autocorrelation in the residuals.

Table 7: Autocorrelation test results

Breusch-Godfrey Serial Correlation LM Test:			
Null hypothesis: No serial correlation at up to 1 lag			
F-statistic	0.097195	Prob. F (1,12)	0.7606
Obs*R-squared	0.216931	Prob. Chi-Square (1)	0.6414

Second, to test the normality of the residuals, the Jarque-Bera test was applied. The null hypothesis assumes that residuals follow a normal distribution. This hypothesis is rejected if the test statistic is significantly high or if the associated probability is below 5%. According to the results of the test, the probability is above the 5% threshold. Hence, we accept the null hypothesis, implying that the residuals are normally distributed.

Third, to assess whether the variance of residuals remains constant (homoskedasticity),the Breusch-Pagan-Godfrey test was performed. The null hypothesis posits that the model is homoskedastic (i.e., the variance of residuals is constant), while the alternative assumes heteroskedasticity. The null hypothesis is rejected if the Fisher test value or the associated probability is below 5%. In this case, the test produced a probability value greater than 5% (Prob. F = 0.9074). As such, we do not reject the null hypothesis and conclude that the residuals are homoskedastic.

Table 8: Heteroskedasticity test results

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
Null hypothesis: Homoskedasticity			
F-statistic	0.468766	Prob. F(13,13)	0.9074
Obs*R-squared	8.617221	Prob. Chi-Square(13)	0.8012
Scaled explained SS	2.766072	Prob. Chi-Square(13)	0.9987

Finally, the stability of the model was tested using the Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ) tests. These tests assess whether the model's coefficients remain stable over time. The null hypothesis in this context states that the vector of coefficients remains unchanged throughout the study period. According to

Bahmani-Oskooee and Ng (2002), if the plots of the CUSUM and CUSUMSQ statistics remain within the 5% significance boundaries, the null hypothesis of parameter stability cannot be rejected. The results of these tests confirmed that the regression model is stable over the period of analysis, as both test plots remained well within the critical bounds.

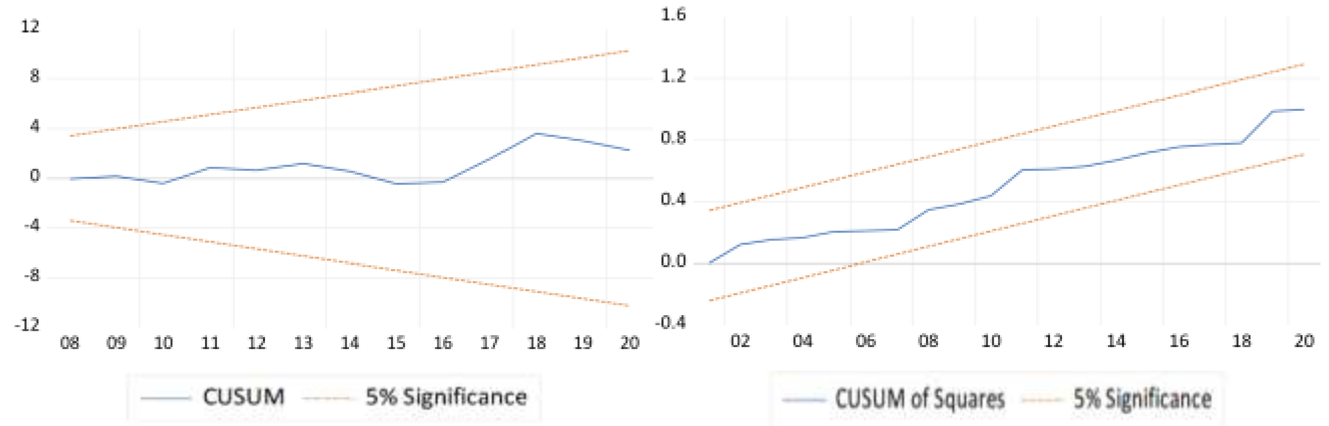

Figure 1: Stability test results

5. CONCLUSION

Although agricultural economic growth and renewable energy consumption in various economic sectors have been extensively studied, the role played by renewable energy sources in the agricultural economic growth of a country has received less attention, particularly in Africa. In this study, we analyzed the short- and long-term causal relationships between renewable energy consumption and Morocco's economic growth, as measured by real gross domestic product.

This study examined several explanatory variables in relation to agricultural GDP, measured by the logarithm of agricultural GDP. The results provide important insights into the relationships between these variables and the economic performance of the agricultural sector in Morocco.

First, the analysis revealed a significant inverse relationship between CO2 emissions and agricultural GDP. The negative coefficient of CO2 emissions, associated with a very low p-value, suggests that CO2 emissions have a negative impact on agricultural GDP over time. This indicates that policies aimed at reducing CO2 emissions could potentially stimulate economic growth in the agricultural sector.

In contrast, employment, represented by the coefficient of LOGEMP, was not found to be statistically significant in its long-term impact on agricultural GDP in the model considered. This highlights that other factors may play a more important role in determining the economic performance of the agricultural sector.

Renewable energy consumption, measured by LOGENERGIE, was also examined. The results showed a significant negative relationship between energy consumption and agricultural GDP. This implies that a decrease in energy consumption is associated with an increase in agricultural GDP. These results suggest that policies promoting the use of renewable energies could help support the growth of the agricultural sector.

Finally, the analysis also highlighted a significant positive relationship between trade, represented by LOGTRADE, and agricultural GDP. This suggests that increased trade is associated with higher agricultural GDP, emphasizing the importance of trade for the economic development of the agricultural sector.

In light of the findings of this study, several recommendations can be proposed to strengthen sustainable agricultural growth in Morocco. First, it is essential to implement effective policies aimed at reducing CO2 emissions in the agricultural sector by promoting sustainable farming practices and improving energy efficiency. At the same time, actively promoting the integration of renewable energies into farming operations would not only reduce the carbon footprint but also improve resilience to fluctuations in energy costs. Although employment in the agricultural sector did not show a significant impact on agricultural GDP in this study, it remains crucial to strengthen initiatives that support rural employment and agricultural entrepreneurship. Moreover, facilitating trade openness and market access for agricultural products is vital to stimulate the sector's productivity and competitiveness.

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