Economic Development and Renewable Energy Nexus in Morocco: Co-Integration and Causality

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Citation: Benyetho, Y., & El-Attar, A. (2023). Economic Development and Renewable Energy Nexus in Morocco: Co-Integration and Causality. *Finance & Economics Review 5(1),* 40-54. https://doi.org/10.38157/fer.v5i1.557

Research Article

Abstract

Purpose *The present study explores the causal relationships between economic development, renewable energy consumption, nonrenewable energy consumption, and CO_2 emissions in the context of Morocco.*
Methods *The panel unit root test, Auto Regressive Distributed Lag (ARDL), and bounds test were used to assess the co-integration of the variables in the study and the long-run relationship between them. It employs the Granger causality test using a vector error correction model to determine the existence and direction of causality among the variables. It uses Morocco's annual statistical data from 1990 through 2019.*
Results *The co-integration of the variables in the study was confirmed, implying that a long-run relationship exists between them. The causality test results suggest that a bidirectional causality exists between renewable energy consumption and economic development, which validates the feedback hypothesis of the mutual link between renewable energy consumption and economic development.*
Implications *These findings suggest that Morocco's economic development is critical in providing the required resources for sustainable development. It also implies that boosting renewable energy utilization would enhance Morocco's economic development and limit environmental degradation.*

Keywords: Fossil Energy, Renewable Energy, Economic Development, ARDL, Morocco

1. Introduction

Reducing global carbon emissions is considered one of the methods to preserve our natural environment. However, Greenhouse gas emissions (GHG), particularly carbon dioxide (CO_2), are increasing day by day due to the growing energy consumption. This is primarily caused by industrialization, population growth, and transportation. Fossil fuels represent nearly 81% of all primary energy sources worldwide, with 31.1%, 28.9%, and 21.4% for oil, coal, and natural gas respectively (Cherni & Jouini, 2017).
Numerous studies have supported the idea that CO_2 emissions increase when conventional energy sources are used. This increase in emissions harms the ecology (Shahbaz et al., 2013). In addition, according to Yang & Li (2017), massive emissions of greenhouse gases like carbon dioxide, nitrous oxide, and methane are to be blamed for environmental degradation. As stated by Ridzuan et al. (2020), in 2018, global energy demand increased by 2.3% due to strong global economic performance, and as a result, global energy-derived CO_2 emissions rose by 1.7%. Furthermore, other major causes for concern are the significant uptick in both demand and prices for fossil fuels, as well as the depletion of traditional energy sources.

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Energy has long been regarded as a key factor in economic growth (Yilanci et al., 2021). That is to say, energy is essential for the industrialization and socio-economic development of both developing and developed nations. It is generally believed that energy supply, among other infrastructural facilities, is crucial for promoting economic growth and maintaining sustainable economic development (Rim & An, 2022). However, since the turn of the century, countries have been confronted with a wide range of energy-related challenges. As it happens, using traditional energy sources has led to major issues on a worldwide scale, including rising levels of energy use and demand, pollution, water scarcity, climate change, and health potential risks (Bamisile et al., 2021). As a result of these issues, nations and organizations around the world have been looking for clean energy solutions (Ozcan & Ozturk, 2019) while keeping in mind the need to balance economic growth with environmental conservation.

The transition from traditional to renewable energy (RE) has gained international attention over the past two decades. Energy transition refers to the process of switching from a conventional energy system, that relies on fossil fuels (oil, gas, and coal) that produce greenhouse gases and are eventually depleted, to one that relies on renewable energy sources such as wind, solar, hydro, biomass, and geothermal energy (Bouyghrissi et al., 2021). Hence, many countries, including the Kingdom of Morocco, have committed to shifting their energy policies toward the promotion of renewable energy sources, as seen by the recent changes to their legislative and regulatory frameworks. Many researchers and experts around the world have underlined that RE may play a critical and extremely essential role in economic development (Boubaker & Omri, 2022; Keček et al., 2019; Naseri et al., 2016; Shidong et al., 2022), the decrease of greenhouse gas emissions (Ali et al., 2022; Mirziyoyeva & Salahodjaev, 2022; Rahman et al., 2022; Singh & Kumar, 2022; Zoundi, 2017), the production of additional power (Azam et al., 2021), and the creation of new jobs (Dvořák et al., 2017; Ram et al., 2020; Saboori et al., 2022).

Since the seminal research by Kraft & Kraft (1978), there have been many papers discussing the relationship between energy consumption and economic growth, yet there is still a lack of consensus among researchers regarding whether energy consumption leads to economic growth or vice versa (Ozcan & Ozturk, 2019). There are different connections between renewable energy consumption, economic growth, CO_2 emissions, and other factors that have been uncovered in the literature (Adams et al., 2018; Apergis & Payne, 2011; Aydin & Aydin, 2013; Bekun et al., 2019; Lu, 2017; Menyah & Wolde-Rufael, 2010; Somoye et al., 2022; Soukiazis et al., 2017; Usman et al., 2021). A variety of empirical methods were utilized to compile those studies. It appears that the results depend on the characteristics of the sample, the variables employed, and the period of the study. For instance, in a study of EL-Karimi & El-houjjaji (2022) on G7 countries from 1980 to 2020, results vary by country: for the US and Canada, economic growth (GDP) positively impacts renewable energy consumption (REC), a positive causal effect runs from REC to GDP in Germany, and there is no relationship between the two in the rest of the G7 countries (France, the UK, Italy, and Japan). It is also perceived that the number of scientific publications on renewable energy is directly related to the economic situation of the country where the research is conducted (Wisz et al., 2018).

Working on the case of Morocco, it is revealed that energy consumption is dependent on energy imports. In addition, this country is among the nations with the highest water stress levels and precipitation decreases in the globe (Farhani et al., 2021). Furthermore, it is worth investigating the impacts of the country's energy transition, namely if it has been successful in maximizing its renewable energy potential and managing the increasing energy demand. Morocco intends to fully utilize renewable energy sources, namely solar energy parks and wind farms, to cover all of its energy needs. The area's favorable climate explains the nation's propensity to create and assess such systems (Kharrich et al., 2019). In light of these developments, our paper aims to re-analyze the energy-growth nexus in Morocco for the period from 1990 to 2019, through the study of the dynamic interactions between economic development, CO_2 emissions, non-renewable and

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renewable energy consumption. Our findings may help policymakers decide whether to encourage renewable energy consumption and restrict the use of nonrenewable energy sources.

2. Literature Review

In reality, several nations express the concern that, if traditional energy use is reduced, they may experience energy shortages that will prevent them from achieving the anticipated economic goals. However, there is also a strong consensus in the scientific community that renewable energy can stimulate the economy and successfully displace fossil fuels. With a multiplier influence on the economy and the social realm, renewable energy promotes sustainable development. Therefore, its development ought to promote rather than inhibit economic development.

Studies that analyze and model the link between economic development and renewable energy have gained substantial relevance since the dawn of the new millennium. The development of renewable energy improves the energy system, which results in a decrease in dependence on petroleum imports and a reduction in harmful emissions. hence, in the long term, renewable energy should favorably affect economic development, according to the prevailing viewpoint (Viktorovna et al., 2021). The rate of development of renewable energy, however, is influenced by a variety of variables and national situations.

Due to differences in nations, the use of different econometric methods, and periods, previous research on the energy-growth nexus has produced mixed findings. These outcomes could be divided into three strands of causality (unidirectional, bi-directional, and neutral causality directions). On another note, regarding the relationship between the GDP and the consumption of clean energy, four main hypotheses are thought to exist. These hypotheses are briefly discussed below.

2.1. Growth Hypothesis

The first hypothesis emphasizes how the consumption of renewable energy affects economic development (the growth hypothesis). In other words, energy consumption is crucial for economic growth, and other factors (such as capital, labor, and technological advancement) cannot compensate for energy's crucial role in the production process. This suggests that any drop in energy use may result in a decrease in economic development. For example, in the case of 32 European countries, Doğan et al. (2020) demonstrate how renewable energy is crucial for boosting economic development. their study investigates the relationship between the consumption of clean and non-renewable energy sources and economic growth, taking into account the moderating effects of institutional quality, trade openness, foreign direct investment (FDI), and economic complexity. Their main findings demonstrate that between 1995 and 2014, economic complexity, consumption of renewable energy, trade openness, FDI, and institutional quality all promote economic growth, while consuming renewable energy is more effective for economic growth than using fossil energy, according to the results for non-renewable energy consumption, which showed both a positive and a negative influence in different quantiles. In addition, Gozgor et al. (2018) propose in their work a growth model that uses economic complexity as an indicator for exporting high-value-added items. Their paper empirically studies the influence of renewable and nonrenewable energy consumption on economic development in 29 OECD nations from 1990 to 2013. It considers ARDL and PQR estimations and concludes that both non-renewable and renewable energy consumption increase economic growth. In a recent study, Wang et al. (2022) examined clean energy sources and their impact on economic growth for 10 selected Asian countries, under sustainable development goal seven. (SDG-7). The SDGs goal (7^{th}) emphasizes clean, inexpensive, and advanced energy systems. They analyzed annual panel data using the Augmented Mean Group (AMG) as well as the Common Correlated Effects Mean Group (CCEMG). Overall, clean energy sources have contributed to these economies' success. In the case of Morocco, Bouyghrissi et al., (2021) used an auto-regressive distributed lag technique and a Granger causality test to examine and assess the nexus and connection between clean and fossil energy consumption, CO_2 emissions, and economic development from 1990 to 2014. The empirical findings confirm that renewable energies are beginning to have a positive effect on the economic aspect of sustainable development in Morocco and a

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causal link is discovered between the consumption of renewable energies and both economic development and CO_2 emissions. In light of this, we conduct our study similarly, yet we extend the time frame until 2019.

2.2. Conservation Hypothesis
The second hypothesis examines how a country's energy consumption is affected by its economic development (the conservation hypothesis). This implies that rising economic activity promotes the consumption of alternative energy sources. For instance, Sadorsky (2009), as one of the earliest author that supports this theory in their work, presented two empirical models of rising economies' renewable energy use and income in G7 countries from 1980 to 2005 and discovered that real per capita income improvements have a statistically significant effect on per capita clean energy consumption, according to panel co-integration estimations. Additionally, Ocal & Aslan's (2013) research that explores Turkey's clean energy consumption–economic development relationship from 1990 to 2010, using Toda–Yamamoto causality tests, displays a unidirectional causality from economic development to renewable energy consumption. More recently, using the Parameterization Autoregressive Distributed Lagged in the Error Correction approach in the study of Somoye et al. (2022) on Nigeria from 1960 to 2019, it was proved that GDP and financial growth support clean energy consumption in the long run, whereas fossil fuels hinder it. In the short run, trade openness reduces renewable energy consumption.

2.3. Feedback Hypothesis
The third hypothesis explores the mutual link between energy consumption and economic development (the feedback hypothesis). According to this hypothesis, there is a two-way causal link (bi-directional causality) between energy consumption and economic development. Consequently, a change in one component influences the other. For example, Apergis & Payne (2012) examine the relationship between renewable energy consumption and economic development for 80 nations from 1990 to 2007. The panel co-integration test shows a positive and statistically significant long-term equilibrium link between real GDP, clean energy consumption, capital, and the labor force, while the panel error correction model shows short- and long-run bidirectional causality between renewable energy consumption and economic development. Moreover, Cherni & Jouini (2017) evaluate the relationship between CO_2 emissions, RENEC, and Tunisia's economic development, using the ARDL model as well as the Granger causality tests for the span of 1990-2015. The findings reveal a bidirectional association between GDP and CO_2 emissions on one hand, clean energy consumption, and GDP on the other hand, but no causality between CO_2 emissions and clean energy consumption. In 16 European countries, Bekun et al. (2019) show, using panel causality analysis to study the long-term causal connection between renewable energy consumption, non-renewable energy consumption, and economic development during 1996-2014, a feedback causality between the three variables of this study. In a more recent study on 10 newly industrialized countries between 1990 and 2015, Azam et al. (2021) found that all variables of their study are co-integrated (economic development, electricity consumption of clean sources, non-renewable electricity consumption, capital formation, labor force, and trade openness), as well as a bidirectional causality between electricity consumption of clean sources and economic development in the short and long-run.

2.4. Neutrality Hypothesis
The fourth hypothesis focuses on the lack of a causal relationship between energy consumption and economic development (the neutrality hypothesis). In other words, energy does not impact economic development, nor does economic development influence energy consumption. For instance, in 27 European countries in the span of 1997-2007, Menegaki (2011) proves that although panel causality tests reveal short-term links between clean energy and greenhouse gas emissions and employment, empirical results do not

support a causal relationship between clean energy consumption and GDP. It is noted that the author used a random effect model and final energy consumption, greenhouse gas emissions, and employment as extra independent variables to clean energy and economic development in the model. In the case of Turkey from 1990 to 2012, in a multivariate model with capital and labor included as extra variables, Dogan (2015) used the Granger causality VECM method to examine the links between economic development, electricity consumption from clean sources, and electricity consumption from fossil sources, and found proof of the neutrality hypothesis between economic development and electricity consumption from renewable sources. Compared to other theories of causality, we noticed that research supporting the neutrality hypothesis is extremely scarce. In this regard, Marinaș et al. (2018) reviewed 48 studies and found that 29% of researchers found evidence in favor of the growth hypothesis, i.e. the effect of renewable energy sources consumption over GDP, 27% found evidence in favor of the feedback hypothesis, and 23% found evidence in favor of the conservation hypothesis. No connections between these two parameters were found by other researchers.

3. Materials and Methods

3.1. Model and Data

Typically, GDP is employed as an indicator of economic development, which may be examined from the "demand" and "supply" sides, when modeling the relationship between economic welfare and clean energy. GDP is viewed as a function that depends on energy resources, their costs, and the amount of carbon dioxide emissions in the first characterizes demand approach. The second method assumes that GDP will be described using the Cobb-Douglas production function. Additionally, this strategy views the use of alternative energy as a sign of advancement in science and technology (Omri & Nguyen, 2014). High-tech industries like renewable energy require specialized staff, cutting-edge machinery, and scientific research to develop. To create renewable energy, the nation must possess adequate financial resources and scientific capability. These prerequisites for creating and utilizing renewable energy are essential, and they can only be met with advanced levels of scientific and technological advancement (Viktorovna et al., 2021).

Many empirical investigations that employ the Granger causality test have focused on the causal relationship in a two-variable setting, although Granger has warned that spurious causality may result from disregarding additional relevant variables. Additionally, Lütkepohl (1982) suggests that overlooked variables in a bivariate system might lead to non-causality. Following Bouyghrissi et al. (2021), through the integration of two variables _ the consumption of fossil energy and CO_2 emissions _ we want to ascertain the effect of clean energy consumption on economic development in Morocco. Additionally, we wish to investigate and analyze the relationships between these variables by using the model below (Equation 1):

$$GDPK_t = \alpha_0 + \alpha_1 TNREC_t + \alpha_2 TREC_t + \alpha_3 CO2_t + \varepsilon_t \text{ ………… [1]}$$

Where GDPK stands for real GDP per capita in current U.S. dollars, TNREC denotes total non-renewable energy consumption (coal, gas, and oil) defined in petajoules (PJ), TREC is the total renewable energy consumption (hydraulic, solar, and wind) also defined in petajoules, CO2 is carbon dioxide emissions in millions of tones and ε_t stands for the error term.

To get over the issue with the data series' distributional properties, all data are converted to natural logarithms (Paramati et al., 2016, 2017; Ummalla & Samal, 2019).

We used annual data from 1990 to 2019 that was attained from the World Development Indicator database (WDI) of the World Bank and the British Petroleum (BP) report: "Statistical Review of World Energy 2020".

We employ the panel ARDL estimation developed by Pesaran, Shin, and Smith (2001) to examine the validity of our economic growth approach, as well as the Granger causality test to evaluate the link between the variables of our study in the short and long run.

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The link between CO_2 emissions, economic growth, and the consumption of renewable and fossil energy is investigated using the ARDL bound testing method.
Compared to the co-integration methods suggested by Engle & Granger (1987) and Johansen & Juselius (1990), the ARDL methodology, developed by Pesaran, Shin, and Smith (2001), provides several advantages. The first is that this method does not require that the variables have the same order of integration. It does, however, consider variables that have order 1 or order 0 integration. It is then adapted for small samples. For the estimation to be accurate, Johansen's co-integration approach needs a lot of observations. Last but not least, the dependent variable in the ARDL model is explained by both its past and the past of the other independent variables.
Then, we estimate the ARDL model of Eq. 2 as follows:

$$\Delta GDPK_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta GDPK_{t-1} + \sum_{i=1}^{p} \alpha_{2i} \Delta TNREC_{t-1} + \sum_{i=1}^{p} \alpha_{3i} \Delta TREC_{t-1} + \sum_{i=1}^{p} \alpha_{4i} \Delta CO2_{t-1} + \emptyset_1 GDPK_{t-1} + \emptyset_2 TNREC_{t-1} + \emptyset_3 TREC_{t-1} + \emptyset_4 CO2_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots [2]$$

where the drift component and the white noise, respectively, are denoted by α_0 and ε_t. The ARDL approach's process is divided into several steps. In this work, the Akaike information criterion (AIC) is first employed to choose the ideal lag length. The F-test is used to conduct the co-integration test as the second step. It is possible to estimate the long-term connection between all variables after the selection of the ARDL model. The ECM can be calculated once this relationship has been established.
The following equation is a general ECM of Eq. 3:

$$\Delta GDPK_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta GDPK_{t-1} + \sum_{i=1}^{p} \alpha_{2i} \Delta TNREC_{t-1} + \sum_{i=1}^{p} \alpha_{3i} \Delta TREC_{t-1} + \sum_{i=1}^{p} \alpha_{4i} \Delta CO2_{t-1} + \omega ECT_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots [3]$$

where (ECT_{t-1}) stands for the error correction term and denotes the long-run relation, while Δ representing the first difference operator.

3.2. Unit Root Test
Any study must first determine whether the variables are stationary. To ascertain the order of integration of the variables at the level I(0) and the first difference I(1), we applied the panel stationarity test approach, provided by Dickey & Fuller (1979), and Phillips & Perron (1988). When the temporal dimension is limited, it is best to apply the Fischer-PP and Ficher-ADF statistics. Moreover, these tests can determine whether a unit root exists in the models.

3.3. Granger Causality Test
According to Engle & Granger (1987), causation only arises in one direction if the X and Y sequences co-integrate in the same order as I (1). To investigate the causal relationships between the indicators, we, therefore, use the panel VECM Granger-causality model because the co-integration approach only offers a long-term relationship; therefore, the direction of causality is required. The VECM causality test analyzes both short- and long-term causal relationships. The short-run causal association is tested by the statistical significance of F-statistics values linked with right-side variables, and the long-run causal relationship is calculated by the meaning of the corresponding error correction term (ECT_{t-1}) using t-test values.
The VECM is expressed as follows (Eq. 4, 5, 6, and 7):

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$$\Delta GDPK_t = \mu_0 + \sum_{i=1}^{p} \mu_{1i} \Delta GDPK_{t-1} + \sum_{i=1}^{p} \mu_{2i} \Delta TNREC_{t-1} + \sum_{i=1}^{p} \mu_{3i} \Delta TREC_{t-1} + \sum_{i=1}^{p} \mu_{4i} \Delta CO2_{t-1} + \emptyset_1 ECT_{t-1} + \varepsilon_{1t} \quad \ldots\ldots\ldots\ldots [4]$$

$$\Delta TNREC_t = \beta_0 + \sum_{i=1}^{p} \mu_{1i} \Delta TNREC_{t-1} + \sum_{i=1}^{p} \beta_{2i} \Delta GDPK_{t-1} + \sum_{i=1}^{p} \beta_{3i} \Delta TREC_{t-1} + \sum_{i=1}^{p} \beta_{4i} \Delta CO2_{t-1} + \emptyset_2 ECT_{t-1} + \varepsilon_{2t} \ldots\ldots\ldots\ldots [5]$$

$$\Delta TREC_t = \gamma_0 + \sum_{i=1}^{p} \gamma_{1i} \Delta TREC_{t-1} + \sum_{i=1}^{p} \gamma_{2i} \Delta GDPK_{t-1} + \sum_{i=1}^{p} \gamma_{3i} \Delta TNREC_{t-1} + \sum_{i=1}^{p} \gamma_{4i} \Delta CO2_{t-1} + \emptyset_3 ECT_{t-1} + \varepsilon_{3t} \ldots\ldots\ldots\ldots [6]$$

$$\Delta CO2_t = \theta_0 + \sum_{i=1}^{p} \theta_{1i} \Delta CO2_{t-1} + \sum_{i=1}^{p} \theta_{2i} \Delta GDPK_{t-1} + \sum_{i=1}^{p} \theta_{3i} \Delta TNREC_{t-1} + \sum_{i=1}^{p} \theta_{4i} \Delta TREC_{t-1} + \emptyset_4 ECT_{t-1} + \varepsilon_{4t} \ldots\ldots\ldots\ldots [7]$$

where (ECT_{t-1}) represents the error correction term and denotes the long-term relation, while Δ stands for the first difference operator.

4. Results

4.1. Correlation between the Variables

The outcome of the multicollinearity between the variables in our model that can be achieved by using the correlation matrix is displayed in Table 1. We discovered that there is a positive correlation between all of the variables. In other words, the GDPK shows a positive correlation with TNREC, TREC, and CO2. Additionally, the TNREC and GDPK, TREC, and CO2 have favorable correlations. Last but not least, there is a positive correlation between GDPK, TNREC, TREC, and CO2 emissions.

Table 1: Correlation matrix

Correlation	GDPK	TNREC	TREC	CO2
GDPK	1.000000			
TNREC	0.959876	1.000000		
TREC	0.796939	0.781375	1.000000	
CO2	0.953511	0.999192	0.777319	1.000000

4.2. Unit Root Test

The outcomes of the ADF and PP tests are shown in Table 2. At the first difference, all variables are stationary and they are I(1).

Table 2: Unit root test

	ADF		PP	
	Intercept	**Intercept and trend**	**Intercept**	**Intercept and trend**
GDP_K	-0.889156	-0.702267	-0.874771	-0.505477
TNRE	-1.796316	-2.552049	-1.875554	-2.391456
TRE	0.912764	-3.433779	-0.767811	-3.047311
CO2	-1.440763	-2.969361	-2.262346	-2.826817
I(1)GDP_K	-4.257337***	-4.197376**	-4.238461***	-4.174802**
I(1)TNRE	-7.085452***	-7.377132***	-7.197793***	-8.252162***
I(1)TRE	-5.343220***	-5.505374***	-8.512447***	-13.85490***
I(1)CO2	-5.080193***	-5.297049***	-7.756359***	-9.719503***

I(1) denotes the first difference operator. ***p value < 1%; **p value < 5%; *p value < 10%

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4.3. ARDL Co-integration Tests

Determining an acceptable lag time for our model is important before performing the co-integration test of Pesaran et al. (2001). Lag 3 was chosen using the Akaike information criterion (AIC), and the outcome is shown in Table 3. The AIC is used to pick our ARDL model (2.3.0.3).

Table 3: Lag length criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	180.1145	NA	4.04e-11	-12.57961	-12.38929	-12.52143
1	265.6226	140.4776	2.87e-13	-17.54447	-16.59290*	-17.25357
2	284.8332	26.07159	2.47e-13	-17.77380	-16.06097	-17.25017
3	313.3063	30.50686*	1.25e-13*	-18.66474*	-16.19064	-17.90838*

*indicates lag order selected by the criterion

Table 4's findings reveal that the error correction coefficient is negative and statistically significant at the 1% level, indicating that the rate of adjustment is roughly 75.02% (CointEq(-1) = 0.750248). Table 3 further shows that while CO_2 emissions have a short-term negative impact on GDP per capita, both total renewable energy consumption and total non-renewable energy consumption have positive effects on GDP per capita. This shows that while carbon dioxide emissions continue to endanger our nation's economic development, both clean and fossil energy sources in Morocco are beginning to have positive effects on the economic aspect of sustainable development.

Table 4: Short-run analysis

Variable	Coefficient	Standard error	t-statistic	Probability
CointEq(-1)	-0.750248	0.139827	-5.365544	0.0001
D(GDP_K(-1))	0.415509	0.149860	2.772644	0.0158
D(TNREC)	1.626661	1.207215	1.347449	0.2009
D(TNREC(-1))	3.010047	1.143051	2.633344	0.0207
D(TNREC(-2))	2.774232	1.373454	2.019895	0.0645
D(TREC)	0.024187	0.031238	0.774279	0.4526
D(TREC(-1))	0.071375	0.035546	2.007948	0.0659
D(TREC(-2))	0.079754	0.027806	2.868264	0.0132
D(CO2)	-1.330283	1.155884	-1.150879	0.2705
D(CO2(-1))	-3.272170	1.096885	-2.983148	0.0106
D(CO2(-2))	-2.492672	1.281951	-1.944436	0.0738
C	-1.811070	0.336852	-5.376463	0.0001

The long-run parameter estimations based on the panel ARDL are shown in Table 5. At a 10% level, the coefficient for total non-renewable energy consumption is statistically significant and positive. A 1% increase in TNREC will raise GDP per capita by 3.39% in the long run. Even if the coefficient is statistically insignificant, Morocco's economic growth continues to be severely impacted by CO_2 emissions. The coefficient for total renewable energy consumption has a negligible effect on economic development and is statistically insignificant because a 1% increase in TREC results in a long-run decline in GDP per capita of 0,097%. The findings regarding TREC are comparable to those of (Yang et al., 2022) in both the short and long run, however, are in opposition to (Espoir et al., 2023) findings.

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Table 5: Long-run analysis

Variable	Coefficient	Standard error	t-statistic	Probability
TNREC	3.391835	1.759452	1.927779	0.0760
TREC	-0.097489	0.087915	-1.108903	0.2876
CO2	-2.115369	1.711437	-1.236020	0.2383

Results of the ARDL co-integration test show a co-integration relationship between GDP_K, TREC, TNREC, and carbon emissions (Table 6). In fact, for the 10%, 5%, and 1% significance levels, the estimated F-statistic (5.8477) is higher than the superior and inferior critical bound values.

Table 6: *F*-bounds test

Test statistic	Value	Significance	I(0)	I(1)
***F*-statistic**	5.847779	10%	2.72	3.77
k	3	5%	3.23	4.35
		2.5%	3.69	4.89
		1%	4.29	5.61

4.4. Causality Test

The Granger causality test is run on four variables related to the relationship between economic development, clean energy consumption, fossil energy consumption, and CO_2 emissions. We observe bidirectional causality between TREC and GDP_K at the 10% significance level and unidirectional causality from TREC to TNREC at the 5% significance level in the short term, according to the VECM model (Table 7). The TREC result is in line with the results of Apergis & Payne, (2014) for 25 OECD countries, Bildirici & Ersin (2015) for the USA, and Ahmed & Shimada (2019) for emerging and developing economies. Moreover, the (ECTt -1) for GDP and TREC, respectively, are significant at the 1% and 5% significance levels because their lag error factors have the anticipated negative signs, indicating that there is a one-way causal relationship connecting TREC and GDP in the long run.

Table 7: Granger causality test

Dependent variable	Short-run				Long-run
	GDP_K	TNREC	TREC	CO2	ECT(-1)
GDP_K	-	4.257 (0.1190)	4.742 (0.0934)*	4.357 (0.1132)	-0.833 [-3.610]***
TNREC	0.095 (0.9535)	-	0.095 (0.9536)	3.698 (0.1574)	0.002 [0.029]
TREC	11.096 (0.0039)***	6.610 (0.0367)**	-	3.632 (0.1627)	-3.072 [-2.363]**
CO2	0.202 (0.9041)	2.780 (0.2491)	0.143 (0.9308)	-	-0.079 [-0.4]

***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively

4.5. Parameter Stability

We will examine the long-term evolution of these parameters because the instability of the model's parameters can affect the outcomes. We used the cumulative sum of recursive residuals (COSUM) and COSUM of square (COSUMs) tests to evaluate the results' robustness and the short- and long-run parameter stability in the co-integrating equation where GDP per capita is the dependent variable. The ARDL model utilized in this work is stable, and there is no heteroscedasticity issue, as seen in Figures 1 and 2, which show that the curve is within the critical interval at the 5% significance level.

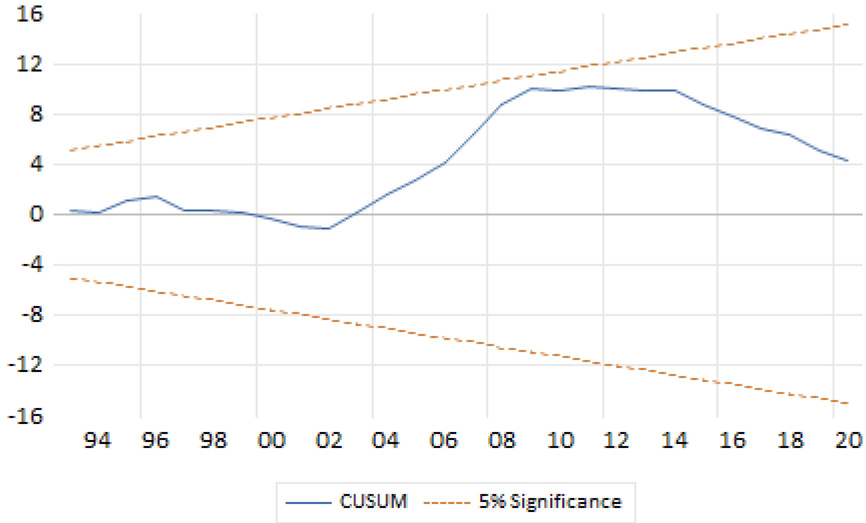

Fig. 1. CUSUM

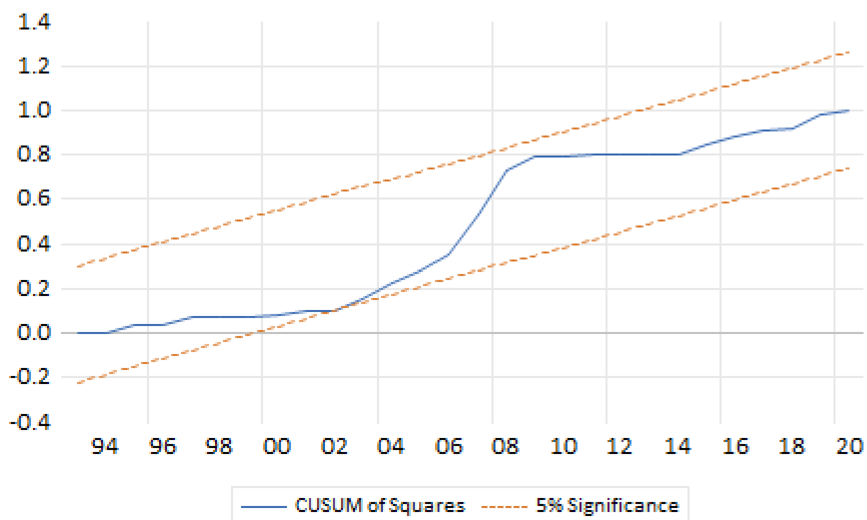

Fig. 2. CUSUM of squares

5. Discussion

The feedback hypothesis is supported by the significant bi-directional causality, which shows that real GDP and renewable energy consumption have a significant mutual effect. This hypothesis suggests that economic activity is a crucial factor in supplying resources for the continued development of renewable energy (Apergis & Payne, 2010). Furthermore, regulations that restrict the use of clean energy might hinder economic development and reduce the market for renewable energy.

Likewise, the results that demonstrate that TREC has a favorable effect on GDP per capita, confirm that the RE sector performs as expected in enhancing economic development. However, in the long run, this influence that shifts to a negative one could be attributed to the debt that must be repaid as a result of the high cost of developing and sustaining clean energy systems. According to Schinko et al. (2019), despite Morocco's location in one of the world's most advantageous areas for the production of solar and wind

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energy, considerable financial hurdles that threaten clean energy sources in the electricity sector (RES-E) development at scale continue to exist. Different investment risk profiles and risk perceptions between nations and technologies result in variations in the cost of financing for specific technologies, which ultimately results in variations in generation costs. Investors' perceptions of risk are especially high for developing nations and RES-E technologies, which are both characterized by substantial capital expenditures. When compared to conventional technologies, this could result in relatively high generating costs for some RES-E technologies (such as concentrated solar power (CSP)) and may eventually deter large-scale capital-intensive RES-E investments.

We may also conclude that, both in terms of statistical significance and the amount of its marginal impact, the effect of economic development is greater in the consumption of clean energy than in the consumption of fossil fuels. This can be seen as proof that our nation is gradually moving toward attaining the fundamental objective of creating green energy projects to safeguard the environment.

It was believed that Morocco's reliance on imported energy should serve as a motivator for the development of non-fossil energy alternatives to prevent balance of payments issues. On the other hand, our findings show that TNREC has a higher favorable impact on GDP per capita than TREC. Therefore, both from the perspective of the significance level and the impact size, the evidence that our country's reliance on imported energy (which is primarily fossil-based) should be a motivation to develop alternative energy sources is not strong.

At last, because the time frame of this study spans from 1990 to 2019, the findings could vary with time, particularly in light of the impact of the COVID-19 pandemic. Overall, it is challenging to forecast what the COVID-19 epidemic will entail for the energy industry and the transition to renewable energy due to the dynamic nature of the issue. According to recent research, Akrofi & Antwi (2020) state that interruptions like COVID-19 are not always harmful because they can bring opportunities that can be used to advance the clean energy transition. The majority of the government economic stimulus plans examined for this study do not specifically state how to shift to clean energy. The development of independent funding options specifically for clean energy companies in response to COVID-19, however, raises the possibility that the African renewables industry may experience a considerable uptick in the years following COVID-19.

6. Conclusion and Policy Recommendations

Renewable energy has developed as an energy source with the potential to address growing anxieties over greenhouse gas emissions, high and fluctuating energy prices, and reliance on conventional energy sources, not to mention the geopolitical climate linked to nonrenewable energy production in certain regions of the world. Therefore, clean energy has a favorable impact on economic growth since it enhances countries' energy supply, creates wealth through the use of different energy sources rather than relying primarily on fossil fuels, and lays the groundwork for the development of high-tech sectors of the economy.

Taking into account Morocco's heavy reliance on foreign energy sources and the environmental damage that fossil fuels cause, it is interesting to explore clean energy sources. This study examines the long-run relationship as well as the causality between clean energy consumption and economic development in Morocco by including non-renewable energy and carbon dioxide emissions in a multivariate framework. Over the period 1990 - 2019, ARDL (Autoregressive distributive Lag) bounds testing approach is carried out, followed by the co-integration approach and the Granger causality analyses. Furthermore, the negative statistical significance of the error correction term and the CUSUM and CUSUMQ methods for stability testing both provide strong evidence for the validity of the ARDL model's findings. Co-integration between the variables has been confirmed by the results.

The findings of the causal connection between energy consumption and economic development indicate a bidirectional causality between economic development (GDP per capita) and TREC and a unidirectional causality running from TREC to TNREC, but no causality running from TNREC to economic development in the short nor in the long run. Moreover, the results show that when comparing clean and fossil energy consumption, the ECT(-1) is more statistically significant for TREC. In other words, the results of the

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VECM approach support the feedback hypothesis because there is both short-term and long-term bidirectional causation link between clean energy consumption and Morocco's economic development. This suggests that in the event of an economic downturn, ramifications may slow the adoption of clean energy and the growth of the renewable energy industry. We discover that clean energy consumption has a favorable impact and promotes economic development in Morocco, despite the modest share of clean energy in this country's energy mix. This implies that Morocco's economic growth could be hindered by renewable energy consumption decrease. In addition to reducing carbon emissions, switching to renewable energy sources would also lessen the reliance on imported energy sources, namely fossil fuels.

Given these findings, the Kingdom of Morocco must keep investing in clean energy technology, R&D, and market facilitation if it wants to strengthen the renewable energy sector and increase its economic viability. By the same token, a strong economy is crucial to the growth of the clean energy industry. Policy measures that promote the exploitation of renewable energy, e.g., tax credits for renewable energy generation, rebates for the deployment of clean energy systems, clean energy portfolio standards, and the formation of markets for sustainable energy certificates, boost economic growth. Other than this, to get the most out of renewable energy, the authorities should create a conducive economic outlook by improving macroeconomic stability, property rights, transparency, ideal governance, infrastructure, and openness to trade. The non-economic constraints are meant to be eliminated, such as grid access, administrative barriers, shortage of training, and information lack. Further, for the government to support the optimal use of sustainable energy, it must select the most suitable incentive policies, taking into account the most pertinent goals in terms of clean energy, the availability of alternative energy technology, and the budget limits. In this matter, it is important to highlight the prospects for the development of clean energies in our Kingdom other than solar, wind, and hydroelectricity, namely biomass and green hydrogen.

Finally, future studies could look more into the specific types of renewable energy like solar, wind, biomass, and hydroelectric power to find out how they affect economic growth and make more in-depth results. However, it is also important to consider the change in findings resulting from different timespans, variables, and countries' economic structures.

Author Contributions: Yousra Benyetho conceived the idea, collected the data, analyzed it and wrote the paper; Abdelilah El-Attar critically revised the paper for significant intellectual content.

Conflict of Interest: The authors declare no conflict of interest.

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