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How Renewable Energy Consumption is Linked to Economic Growth In Morocco 1990-2021: The Toda- Yamamoto Approach.

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Abstract

This study explores the intricate relationship between renewable energy (RE) consumption and economic growth (GDP) in Morocco, aiming to position RE as a primary driver for GDP expansion while mitigating dependence on fossil fuel imports. Utilizing annual data from 1990 to 2021, the Toda-Yamamoto causality test is applied to unravel the dynamic interconnection between RE consumption and GDP. The findings unveil a noteworthy unidirectional causality, wherein GDP influences RE consumption, signaling that RE has not yet attained the autonomy to propel GDP growth independently. This departure from conventional assumptions underscores the need for a nuanced understanding of the intricate mechanisms linking renewable energy and economic growth. The outcomes of this research bear significant implications for policymakers and economists, offering a critical lens to reevaluate current policies and explore alternative pathways through which RE can become a potent driver of economic growth in Morocco. The study contributes to the discourse on sustainable energy development and underscores the importance of tailored policies that consider the multifaceted dynamics between renewable energy integration and economic advancement.

Keywords: Renewable Energy, Economic Growth, CO2 emissions, Morocco, Toda-Yamamoto Causality Test,

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1. Introduction

Energy is an important factor in the economic progress of every country. It can be utilized differently in both industrial activities and households such as automobiles powering, industrial machinery and cooking. Developing and developed countries are pursuing economic growth and sustainable development, yet climate change has generated environmental concerns that are increasing the demand for renewable energy technologies.

In 2018, the International Energy Agency (2019) reported that the global energy consumption witnessed an almost twofold increase in its average growth rate compared to the levels observed in 2010. This surge in consumption has led to an escalating demand for energy. Notably, electricity demand constituted half of the overall global energy demand, with fossil fuel demand experiencing a substantial 70% growth. Among fossil fuels, natural gas saw the most significant rise, contributing to a 45% increase. Although renewable energy consumption doubled in the same period, it was insufficient to meet the expanding global electricity demand. The heightened reliance on non-renewable energy sources globally has contributed to a 1.7% increase in CO_2 emissions.

Morocco relies significantly on energy imports, with approximately 90% of its energy sourced from abroad. This dependence has substantial implications for the country's balance of payments, particularly since some energy supplies receive government subsidies. The predominant use of fossil fuels in Morocco gives rise to two primary challenges: ensuring the security of energy supply and managing a relatively high level of greenhouse gas emissions.

In the current global context, many countries worldwide are acknowledging their shared responsibility in addressing the climate challenge, prompting a shift towards renewable energy sources. In alignment with this trend, Morocco has undertaken significant strategic reforms and implemented new public policies to facilitate an effective transition to a greener economy characterized by lower CO_2 emissions. Notably, the reduction of public subsidies for petroleum products has created a conducive environment for the development of renewable energies while also optimizing the consumption of fossil fuels.Aware of the interest in investing in this sector, Morocco has given great importance to the subject of renewable energies through the implementation of structural reforms. For this reason, Morocco launched its national energy strategy in 2009. The strategy aims to ensure the security of supply, generalize access to energy, and control demand, while preserving the environment. It is particularly based on the mobilization of national resources through the rise of renewable energy resources and their use

To achieve these objectives, Morocco plans to increase the volume of investments in this sector by 40 billion$ by 2030, including 30 billion$ for renewable energy (OME, 2021). It also aims to change the structure of energy consumed by giving a higher share to renewable energies, which would rise from 42% in 2020 to 52% in 2030 (Ministry of energy transition and sustainable development of Morocco)

This paper aims to address two key research questions pertaining to the relationship between renewable energy consumption and economic growth in Morocco from 1990 to 2021. Specifically, the inquiries revolve around understanding the nature of this relationship and assessing whether Morocco has effectively positioned renewable energy as a driver of its Gross Domestic Product (GDP).

The structure of the paper is as follows, the subsequent section delves into the developments within the renewable energy sector in Morocco. Following that, Section 3 provides a comprehensive literature review, summarizing studies that have explored the connection between renewable energy consumption and economic growth. Section 4 outlines the methodology employed and details the data used in the analysis. The empirical results are discussed in Section 5. Finally, Section 6 encapsulates the paper with the conclusion and recommendations.

2. The renewable energy sector in Morocco

Due to population growth and the modernization of national industry, growth in demand for primary energy and electricity in Morocco has averaged 5.7% and 7% per year respectively over the past ten years, when almost 80% of electricity is generated by fossil fuels. In order to fulfill its energy requirements, Morocco heavily relies on importing nearly all of its energy needs. This dependence places a substantial burden on the country's balance of payments and overall economy. A crucial focus for Morocco is the promotion of renewable energy sources, including solar, wind, and hydro power. This initiative is pivotal for the nation as it aims to diminish its reliance on energy imports, bolster the security of its energy supply, generate new employment opportunities, and mitigate the risk of heightened pollution.

As previously stated, Morocco's heavy reliance on costly imported energy resources has raised significant apprehensions regarding energy supply security and the nation's balance of payments. To address these concerns, Morocco has pursued an energy strategy since 2009 that prioritizes the development of energy efficiency and the enhancement of renewable energy capacity. The aim is for renewable energies to assume a prominent position in the national energy mix, playing a central role in both the ongoing energy transition and the evolution of the

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country's economy. This strategic approach is articulated through roadmaps featuring short, medium, and long-term objectives, coupled with a clear vision guiding legislative, regulatory, and institutional reforms.

Since the launching of this energy strategy in 2009, Morocco has recorded significant progress and advances in the energy sector thanks to its energy policy aiming at the differentiation and diversification of energy sources as well as the efforts to further develop energy from renewable sources (solar, wind, and hydro). To support the growth of the renewable energy sector and ensure the success of the energy strategy, Moroccan authorities have enacted Law No. 13-09 specifically addressing renewable energies. Comprising 44 articles, this legislation is designed to work in conjunction with the national energy policy, aiming to develop and align the renewable energy sector with future technological advancements while fostering private initiatives. In alignment with this, various programs have been implemented with positive outcomes.

During the period from 2009 to 2013, the National Priority Action Plan (NPAP) was initiated. Its primary objective was to restore the equilibrium between electricity supply and demand by focusing on the rationalization of energy usage and reinforcing production capacities, leading to the addition of 1400 MW in power generation.

2013 marked a turning point in this energy transition process with the contribution of renewable energy sources (water and wind) increasing to 16.2% of overall electricity production instead of 4% in 2009. Hydroelectric production followed the same pace to reach11.15% in 2013.

The target established for 2020 was to elevate the contribution of renewable energies to 42% of the total installed electrical capacity. To meet this goal, comprehensive programs were initiated with the objective of installing 6000 MW of renewable sources, distributed as follows: 2000 MW for wind energy, 2000 MW for solar energy, and 2000 MW for hydroelectric energy.

In a concerted effort to expedite its energy transition, Morocco has heightened its ambitions by revising the target, now aiming to increase the share of renewable energy from the initially planned 42% of installed capacity in 2020 to an elevated goal of 52% by the year 2030 (Figure 1).

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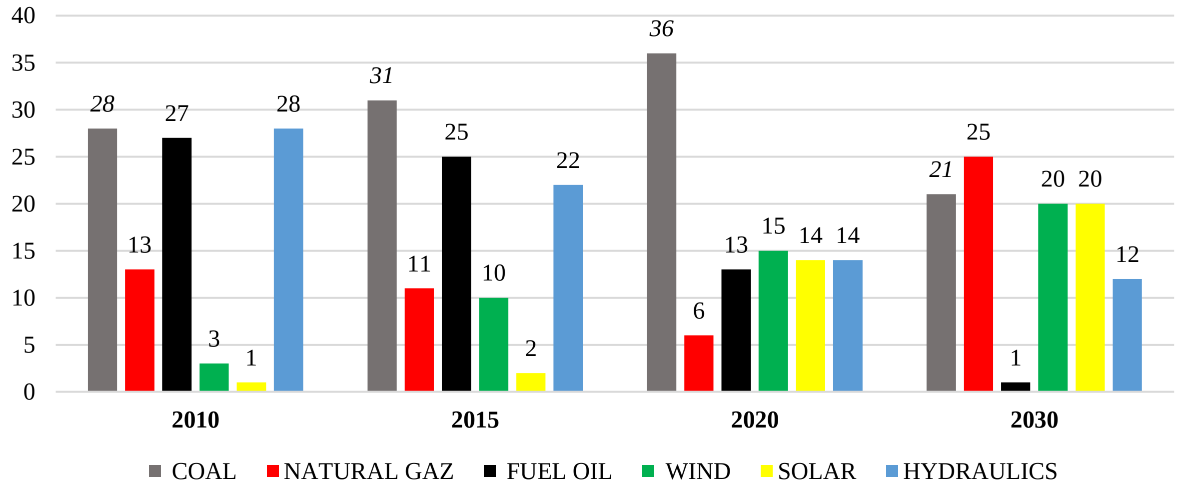
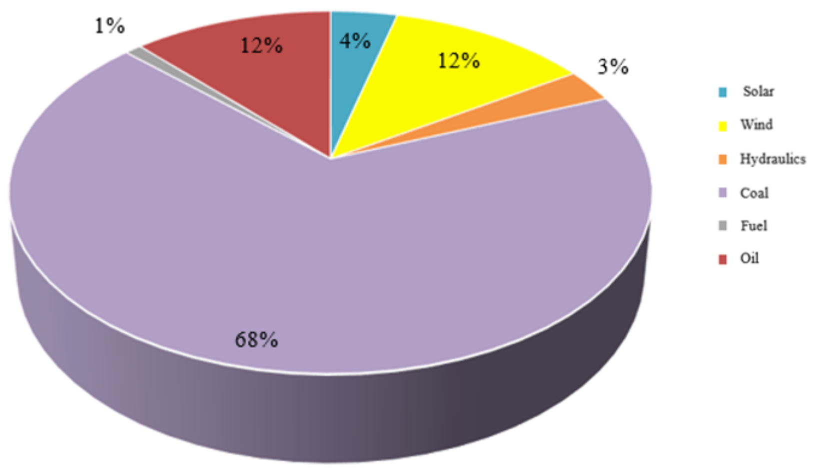
Figure N°1: Development prospects for renewable energy in Morocco: evolution of the electricity mix 2010-2030 in %



Source : MASEN

Figure N°2: electricity produced from different sources of energy (2019)



Source : ONEE

As shown in Figure 2, renewable energy sources contributed 19% of the country's electricity supply in 2019. Most of this contribution came from wind power (63% of total renewables). The share of hydropower was 16% (of total renewables) and has been steadily decreasing in the face of the growth of solar and wind power. Until 2013, hydropower was still the main source of renewable energy, with a 66.5% share of electricity generation from renewable sources. Although its installed capacity is much lower than that of hydropower, wind power has been the leading renewable electricity source since 2014. (Ministry of energy transition and sustainable development of Morocco)

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In 2019, the proportion of electricity derived from renewable energy sources stood at approximately 20%, a figure deemed inadequate. In response, a new legislation, Law No. 40-19, was formulated to amend and complement Law 13-09 concerning renewable energies. This process involved extensive consultations with private entities, public institutions, and relevant ministerial departments. The primary objective of this legislative update is to enhance the legal and regulatory framework overseeing the implementation of renewable energy projects by the private sector. Simultaneously, the law aims to ensure the security and sustainability of the national electricity system and maintain equilibrium across all its components.(Energies renouvlables.men.gov.ma)

This draft law, which was approved by the Government Council on July 1, 2021, and sent to Parliament for approval, is in line with the guidelines of Morocco to improve the business climate, strengthen transparency, facilitate access to information on investment opportunities and improve authorization procedures. This would likely strengthen the attractiveness of the renewable energy sector to private national and international investment and accelerate the emergence of a national ecosystem of renewable energy technologies.(Energies renouvlables.men.gov.ma)

2.1. The renewable energy balance sheet in 2021 under the energy strategy

- A total of 111 renewable energy projects have either been completed or are currently in development.
- The total capacity of renewable sources has reached 3950 megawatts, making up around 37% of the overall electricity composition. This comprises 710 megawatts from solar, 1430 megawatts from wind, and 1770 megawatts from hydroelectric sources.
- In 2021, renewable energies contributed about 20% to the overall electricity production.
- The energy dependency ratio has witnessed a decline, decreasing from 97.5% in 2009 to 90.51% in 2021, showcasing a positive trend towards reduced reliance on external energy sources.

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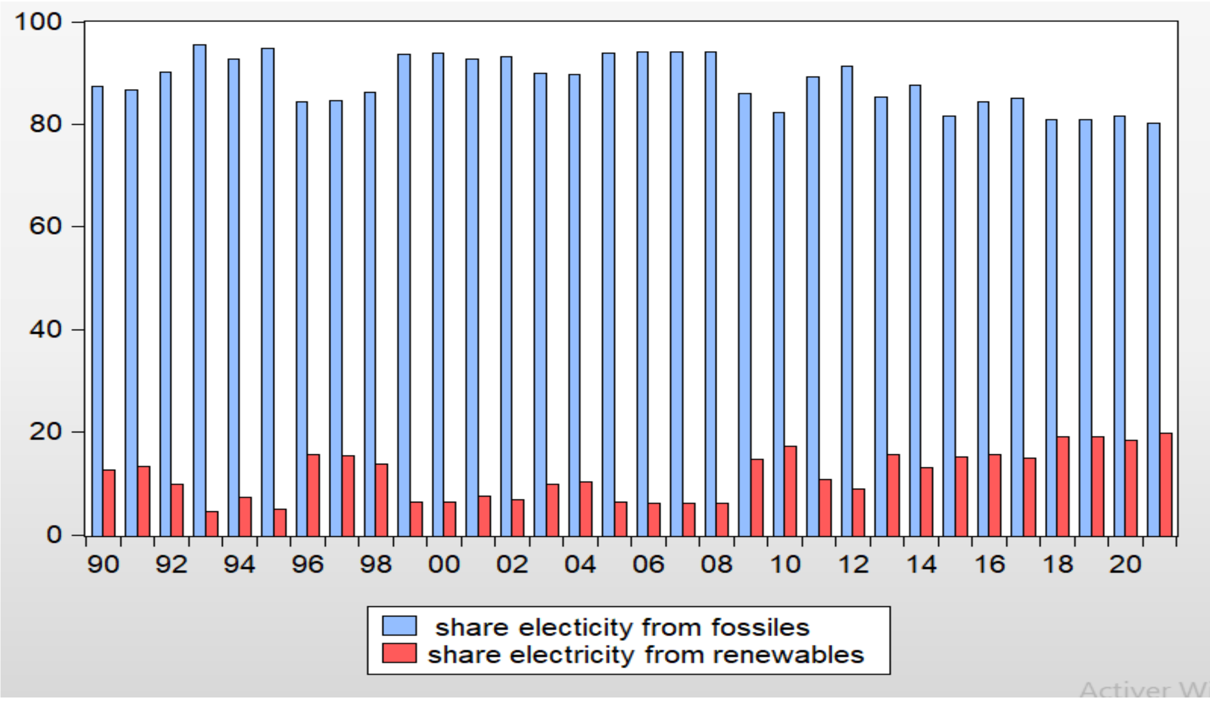
2.2. Overview of the development of electricity generation from renewable and fossil fuels in Morocco between 1990 and 2021

Figure N°3: Electricity rates generated by renewables and fossil fuels



Source: Author, Word Bank Indicator

As shown in Figure 3, electricity generation from fossil fuels is still dominant and the percentage of electricity generated from renewable sources does not exceed 20% at best. This situation reflects the inability of the progress made in installing renewable energies to compete with fossil fuels

3. Literature Review

The empirical and theoretical literature presents diverse perspectives on the causality directions—neutral, unidirectional, and bidirectional—between renewable energy consumption and economic growth. The global landscape witnessed the significant impact of interactions among renewable energy consumption, economic growth, and the environment, particularly following the 1978 oil crisis. Consequently, extensive research has been conducted to explore the relationship between renewable energy consumption and economic growth. Four hypotheses provide varying insights into the causal link between renewable energy consumption and economic growth. The Growth Hypothesis asserts a one-way causality, positing that economic growth is positively influenced by renewable energy consumption. According to this viewpoint, factors like capital, labor, and technological advancements cannot

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adequately substitute for the positive impact of utilizing renewable energy. Consequently, any reduction in renewable energy usage may correspondingly lead to a decline in economic growth. Conversely, the Conservation Hypothesis proposes a unidirectional causality from economic growth to renewable energy use. In this context, policies aimed at reducing the demand for renewable energy may not significantly affect economic growth, as economic growth primarily drives the utilization of renewable energy. Transitioning to the Feedback Hypothesis, it suggests a mutually reinforcing relationship between GDP and renewable energy consumption. An increase in renewable energy consumption leads to a subsequent rise in GDP, and vice versa. Additionally, changes in GDP, whether positive or negative, may similarly influence renewable energy consumption, as evidenced by bidirectional Granger causality. Finally, the Neutrality Hypothesis posits the absence of causality between economic growth and renewable energy consumption. According to this perspective, changes in one variable do not cause changes in the other, suggesting a neutral relationship with no discernible causal link between economic growth and renewable energy consumption. Several noteworthy empirical investigations in this field have been conducted by various researchers. For instance, Sadorsky (2009) conducted a study using data from 1994 to 2003 for emerging economies, employing the panel cointegration model to explore the connection between renewable energy consumption and economic growth. The results indicate that increases in real per capita income have a positive and statistically significant impact on per capita renewable energy consumption. Over the long term, a 1% increase in real income per capita is associated with an approximate 3.5% rise in per capita renewable energy consumption, supporting the conservation hypothesis. Apergis N and Payne (2010) examined data from 1992 to 2007 across 13 Eurasian countries, utilizing a panel model. The outcomes reveal bidirectional causality between renewable energy consumption and economic growth in both short-term and long-term contexts, confirming the feedback hypothesis characterizing the relationship between renewable energy consumption and economic growth. Tiwari (2011) analyzed data from 1960 to 2009 for India, employing Structural Vector Autoregressive (VAR) analysis to explore the interaction between renewable energy consumption and GDP. The study discloses that a positive shock in renewable energy sources leads to an increase in GDP, providing empirical support for the Growth hypothesis. Fang Y. (2011), using data from 1978 to 2008 for China, examined the relationship between renewable energy consumption and economic growth through Ordinary Least Squares (OLS). The findings indicate that a 1% increase in renewable energy consumption (REC) corresponds to a 0.120% increase in real GDP, corroborating the Growth hypothesis. Menegaki (2011) investigated data from 1997 to 2007 across 27 European countries, employing a multivariate panel framework random effect model. The empirical results do not validate causality between renewable energy consumption and GDP, aligning with the neutrality hypothesis. The disparities and inadequacies observed in the relationship between renewable energy consumption and economic growth in Europe can be partly attributed to the uneven and insufficient utilization of renewable energy sources. Tugcu and al. (2012) conducted an investigation using data from 1980 to 2009 for G-7 countries. Employing the Autoregressive Distributed Lag (ARDL) model, their empirical findings support the feedback hypothesis. In a broader global context, Al Mulali and al (2013) examined data from 1980 to 2009 for 108 countries, utilizing Fully Modified Ordinary Least Squares (OLS) tests. The study categorized the countries into four income groups: low-income countries, lower-middle-income countries, upper-middle-income countries, and high-income countries. Notably, 79% of the countries exhibited a positive bidirectional long-run relationship between renewable energy consumption and GDP growth, aligning with the feedback hypothesis. Conversely, 19% of the countries displayed no long-run relationship between the variables, reflecting the neutrality hypothesis. Additionally, 2% of the countries demonstrated a one-way long-run relationship from GDP growth to renewable energy consumption or vice versa, corroborating the conservation hypothesis or the growth hypothesis. Despite diverse outcomes across nations, it is established that countries with more persistent and substantial bidirectional long-run relationships between the variables tend to have higher income levels. The significance of investing in the renewable energy sector is underscored, emphasizing its role in enhancing energy security by reducing reliance on imported fossil fuels. Furthermore, the study highlights the positive impact of renewable energy on job creation. Ocal and Aslan (2013) investigated the interplay among renewable energy consumption, capital, labor, and economic growth in Turkey spanning the years 1990 to 2010, utilizing the Toda-Yamamoto causality approach. The empirical results of the test reveal a unidirectional causality running from economic growth to renewable energy consumption, aligning with the conservation hypothesis. Apergis and Danuletiu (2014) explored the relationship between renewable energy consumption and economic growth across 80 countries using data from 1990 to 2012. Utilizing the Canning and Pedroni (2008) long-run causality test, their findings indicate a long-run positive causality running from renewable energy to real GDP for the overall sample and across different regions, supporting the growth hypothesis. Salim and al. (2014) explored the dynamic relationship between renewable and non-renewable energy consumption, industrial output, and GDP growth in OECD countries over the period 1980 to 2011. Employing the panel cointegration technique with structural breaks, their results reveal a unidirectional causality running from economic growth to renewable energy consumption, supporting the conservation hypothesis. Ibrahiem (2015) investigated the relationship among renewable electricity consumption, foreign direct investment, and economic growth in Egypt, utilizing the ARDL model with data spanning from 1980 to 2011. The empirical results indicate cointegration among the variables, signifying a long-run relationship. Additionally, a bidirectional causality relationship is identified between renewable electricity consumption and economic growth, supporting the feedback hypothesis. Caraini Chirata and al. (2015) explored the relationship between energy consumption from various sources and economic growth in Poland, Hungary, Bulgaria, Romania, and Turkey, using Engle and Granger causality tests. The results support the neutrality hypothesis for Poland, Turkey, and Romania, the conservation hypothesis for Hungary, and the feedback hypothesis for Bulgaria regarding the relationship between renewable energy consumption and economic growth. Hamit Haggar (2016) investigated the relationship between renewable energy consumption and economic growth in 11 sub-Saharan African countries, utilizing Panel causality tests with data spanning from 1971 to 2007. The findings reveal a one-way Granger causality relationship from renewable energy consumption to economic growth, supporting the growth hypothesis. Fotourehchi (2017) examined the relationship between renewable energy consumption and economic growth in 42 developing countries from 1990 to 2012, employing the Panel cointegration test approach. The results indicate a long-term positive relationship between renewable energy and economic growth, supporting the growth hypothesis. Policymakers are advised to prioritize the development of the renewable energy sector over conservation policies for sustainable growth.

Wadad-Saad and al. (2018) analyzed short- and long-term causality between renewable energy consumption and economic growth in 12 European Union countries from 1990 to 2014. The study revealed a unidirectional causality from economic growth to renewable energy consumption in the short term. However, in the long term, bidirectional causality was observed, confirming the feedback hypothesis.

In a study conducted by Ozcan and al. (2019), the causal connection between renewable energy consumption and economic growth was examined in 17 emerging countries spanning the years 1990 to 2016, employing a panel causality test. The outcomes generally align with the neutrality hypothesis for the majority of countries, except for Poland, where the growth hypothesis was validated. This suggests that, for most emerging economies, energy-saving policies do not negatively affect growth rates; however, Poland may face adverse consequences from such policies. Another investigation by El-Karimi and El Ghini (2020) focused on Morocco and explored the causal link between renewable energy consumption and economic growth, taking

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into account capital and labor factors. Utilizing the Toda and Yamamoto causality test on data spanning 1980 to 2016, the findings indicate a significant impact of capital on economic growth, while no substantial causal relationship is identified between renewable energy consumption and economic growth, supporting the neutrality hypothesis. In a separate analysis, Bouyghrissi and al. (2020) delved into the relationship between renewable and non-renewable energy consumption, CO2 emissions, and economic growth in Morocco from 1990 to 2014. Employing the ARDL approach and Granger causality tests, the results affirm a positive influence of renewable energy consumption on economic growth. The authors recommend innovative financing approaches for renewable energy projects in Morocco based on these findings.

Table N°1: Summary of literature on Renewable energy, economic growth nexus

Authors	**Publication years**	**Country/ies**	**Period**	**Methodology**	**Results**
Sadorsky	2009	Emerging countries	1994-2003	Panel model	GDP→RE (conservation hypothesis)
Apergis and Payne.	2010	Eurasia	1992-2007	Panel model	RE↔GDP (feedback hypothesis)
Tiwari	2011	India	1960-2009	Structural vector autoregressive VAR analysis	RE→GDP(Growth hypothesis)
Fang.Y	2011	china	1978-2008	OLS	RE→GDP(Growth hypothesis)
Menegaki	2011	Europe	1997-2007	Panel model	RE─GDP (neutrality hypothesis)
Tugcu and al.	2012	G-7 countries.	1980–2009	ARDL model	RE↔GDP(feedback)
Al-mulali	2013	108 countries	1998-2007	Panel-cointegration test	-85 countries RE↔GDP(feedback) -21 countries RE─GDP(neutrality) -2 countries GDP→RE(conservation)
Ocal,O, Aslan, A.	2013	Turkey	1990-2010	Toda-Yamamoto causality test	GDP→RE(conservation)
Apergis N and Danuletiu D.C	2014	80 countries	1990-2012	Canning and Pedroni (2008) long-run causality test	RE→GDP(Growth)

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Salim and al.	2014	OECD countries	1980-2011	panel cointegration	GDP→RE(conservation)
Ibrahiem	2015	Egypt	1980-2011	ARDL model	RE→GDP.(Growth)
Caraini chirata and al	2015	Poland, Hungary Romania, Turkey and Bulgaria	1980-2013	Gragner and Engle causality test	GDP→RE(conservation) for Hungary - RE↔GDP(feedback) for Bulgaria - ER— GDP(Neutrality) for Poland, Romania and Turkey
Hamit-Haggar	2016	Sub-saharian African countries	1971-2001	panel causality tests	RE→GDP(Growth)
Fotourehchi	2017	42 developing countries	1990-2012	Canning and Pedroni (2008) long-run causality test	RE→GDP(Growth)
Wadad-Saad and Ali Taleb	2018	12 European Union countries.	1990-2014	vector error correction model and the Granger causality	RE↔GDP(feedback)
Ozcan and al.	2019	17 emerging countries	1990-2016	panel causality test	-RE— GDP(Neutrality) for 16 emerging countries - RE→GDP(Growth) for Poland
El-Karimi and EI Ghini	2020	Morocco	1980-2016	Toda et Yamamoto - 1995	RE—GDP(neutrality)
Bouyghrissi and al.	2020	Morocco	1990-2014	ARDL approach and the Granger causality test	RE→GDP(Growth hypothesis)

Source: Author

Note: The abbreviations are as follows

RE: Renewable Energy consumption; **GDP**: Gross domestic product **RE→ GDP**: Unidirectional causality from RE to GDP (Growth hypothesis); **GDP → RE**: Unidirectional causality from GDP to RE (Conservation hypothesis); **GDP ↔ RE**: Bidirectional causality (feedback hypothesis). **ER— GDP**: no causality between GDP and RE (Neutrality hypothesis)

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4. Methods and materials

This study employs the Toda Yamamoto test to investigate the causality between the share of primary energy derived from renewable sources (RE) and economic growth (GDP) in Morocco over the period 1990-2021. Gross Domestic Product (GDP) observations are recorded annually and expressed in constant 2015 US dollars, while Renewable Energy consumption (RE) is represented as the percentage of primary energy consumption derived from renewables. All data used in this study are sourced from the World Bank. The primary objective of the empirical work in this paper is to examine the relationship between GDP and RE using the Toda Yamamoto (1995) causality test, an extension of the Granger non-causality test. Traditional Granger causality tests are applicable only to stationary series, and these series should be of the same order before differentiation (Granger, 1981: p126,127). However, the Toda and Yamamoto (1995) test eliminates the need for information about the system's integration and cointegration characteristics. It can be applied even in the absence of integration or stability, assuming that the maximal order of integration ($dmax$) is less than or equal to the optimal lag (Toda, Yamamoto, 1995).

The TY method employs a modified Wald test (MWALD) to impose restrictions on the parameters of the $VAR(k)$, where k represents the lag length of the system. The fundamental concept of the TY approach involves expanding the correct order k by the maximal order of integration, $dmax$. After this expansion, a VAR of order ($k + dmax$) is estimated, with the coefficients of the last lagged $dmax$ vectors being disregarded (Caporal and Pittis (1999)). Given the focus on the relationship between GDP and RE, the equations corresponding to each of these dependent variables are articulated as follows:

$$GDP_t = \alpha_0 + \sum_{i=1}^{k+dmax} \alpha_i \, GDP_{t-i} + \sum_{i=1}^{k+dmax} \Phi_i \, RE_{t-i} + \mu_t$$

$$RE_t = \beta_0 + \sum_{i=1}^{k+dmax} \beta_i \, RE_{t-i} + \sum_{i=1}^{k+dmax} \Omega_i \, GDP_{t-i} + \varepsilon_t$$

In the Toda-Yamamoto test, where "k" represents the optimal lag order, "$dmax$" signifies the maximum order of integration of the series, and "μt" and "εt" represent the error terms. The test is designed to assess causality without requiring prior knowledge of the system's integration and cointegration characteristics. It can be applied under the assumption that the maximum order of integration is less than or equal to the optimal lag. The error terms, μt and εt, capture the residuals or unexplained variations in the series under consideration.

5. Results and discussion

5.1. Statistical analysis

Table 2 provides the statistical information for the series utilized in this study. The Jacque-Bera statistics indicate that all variables considered in the analysis exhibit a normal distribution, as evidenced by the probabilities exceeding 5%.

Moreover, the positive values of skewness for our variables suggest that their distributions are skewed to the right, indicating a tendency for the data to be concentrated on the left side with a tail extending towards the right.

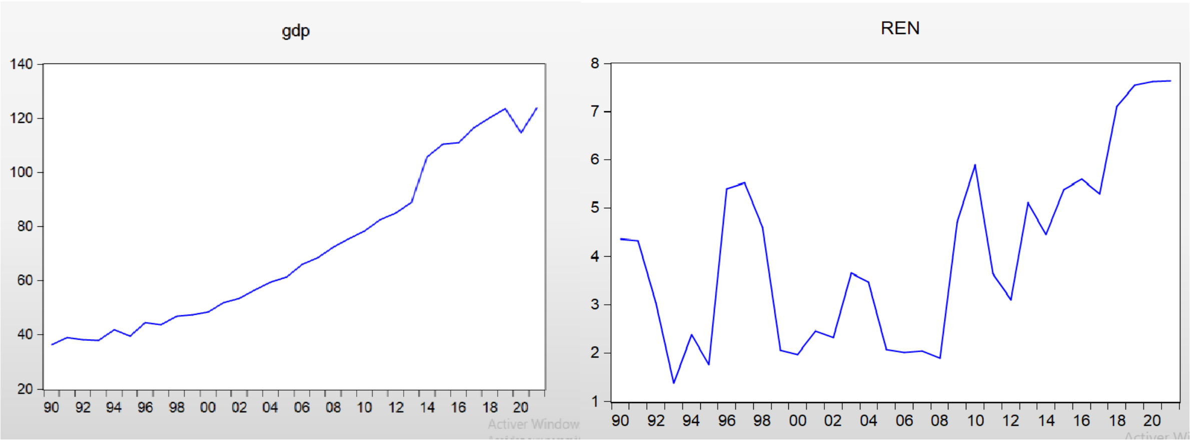
Table N°2: Descriptive Statistics

	GDP	**RE**
Mean.	71.58844	4.059688
Median.	63.76000	3.99500
Maximum	123.8700	7.64000
Minimum	36.3400	1.38000
Std. Dev.	29.79021	1.980384
Skewness	0.525432	0.409289
Kurtosis	1.846842	2.097608
Jacque-Bera	3.245454	1.979175
Probability	0.197360	0.371730
Sum	2290.830	129.9100
Sum Sq. Dev.	27511.15	110.7759
Observations.	32	32

Source: Author, Eviews

The graphical representation indicates characteristics in the time series data that imply a lack of stationarity. For instance, there may be visible trends, cycles, or irregular patterns that do not exhibit a constant mean or variance over time. To substantiate and strengthen this observation, stationarity tests will be conducted. These tests involve statistical procedures to formally assess whether the data exhibit stationary or non-stationary behavior.

Figure N°4: Graphic representation of variables



Source: Author, Eviews

5.2. Toda-Yamamoto test

The Toda-Yamamoto causality test, conducted using a standard VAR (Vector Autoregression) framework, involves the following procedure:

5.2.1. Determination of the maximum order of cointegration

In the initial step, the maximum order of integration ($dmax$) for the variables within the system is established. This study employs the Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) stationarity tests for this purpose. The outcomes, presented in Table (3), reveal that the variables exhibit stationarity in the 1st difference. Consequently, $dmax$ is determined to be equal to 1.

Table N°3: Results of the ADF and PP stationarity test

Variables	ADF(%5)		Philips-Peron(%5)		Integration order
	Level (Intercept)	First difference (intercept)	Level (Intercept)	First difference (intercept)	
GDP	0.839490 (-2.960411)	-5.916917 (-2.963972)	1.096247 (-2.960411)	-5.913893 (-2.963972)	I(1)
RE	-1.571572 (-2.960411)	-4.741073 (-2.967767)	-1.546133 (-2.960411)	-6.611030 (-2.963972)	I(1)

Source: Author, Eviews

5.2.2. Determination of optimal lag.

The second step in the causal test analysis involves determining the optimal lag length (k) using criteria such as LR (Likelihood Ratio), FPE (Final Prediction Error), AIC (Akaike Information

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Criterion), SC (Schwarz Criterion), and HQ (Hannan-Quinn) criteria. A VAR model, encompassing all endogenous variables, is estimated with a randomly selected lag interval. Subsequently, a determination test of the lag interval is applied to the residuals to identify the optimal lag interval.

As per the results in Table 4, all criteria converge on recommending 1 as the optimal number of delays. Therefore, we decide to choose k=1. In alignment with the criteria for minimizing lag length, the retained lag is 1. Since the maximum order of integration does not exceed the optimal lag ($dmax \leq k$), an augmented VAR test with an order of $p = dmax+k$=2 can be applied.

Table N°4: Optimal Lag

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-167.8150	NA	1614.878	13.06269	13.15947	13.09056
1	-113.5405	96.02408*	33.84312*	9.195425*	9.485755*	9.279030*
2	-110.3169	5.207368	36.20119	9.255147	9.739031	9.394488
3	-109.8644	0.661341	48.39964	9.528032	10.20547	9.723110
4	-108.1212	2.279595	59.47349	9.701631	10.57262	9.952444
5	-106.2813	2.122970	74.10369	9.867792	10.93233	10.17434
6	-102.9396	3.341716	84.76642	9.918429	11.17653	10.28072

* indicates lag order selected by the criteria:

LR: sequential modified LR criterion (each test at 5% level)

FPE: Final prediction error criterion

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Source: Author, Eviews

5.2.3. Causality test

Upon determining the order of integration $p= dmax$ + k=2, the third step involves estimating the VAR (2) and applying the Granger causality test using the Toda-Yamamoto method. The results are presented in Table 5.

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Table N°5 Granger causality test based on TY causality test method.

Dependente variable : GDP			
Excluded	Chi-sq	df	Prob
REN	2.194387	2	0.3338
ALL	2.194387	2	0.3338
Dependente variable : RE			
Excluded	Chi-sq	df	Prob
GDP	12.44535	2	0.0020
ALL	12.44535	2	0.0020

Source: Author, Eviews

According to the Toda and Yamamoto causality test, the null hypothesis "RE does not Granger Cause GDP" cannot be rejected. However, the null hypothesis "GDP does not Granger Cause RE" is rejected at the 5% significance level. This implies a unidirectional causal link from GDP to renewable energy (RE). Therefore, it can be inferred that GDP may play a role in boosting renewable energy use in Morocco. These findings align with previous studies, such as Sadorsky (2009) for 18 emerging countries, Ocal and Aslan (2013) in the case of Turkey, Salim and al. (2014) for OECD countries, and Caraini Chirata and al. (2015) for Hungary.

The results are consistent with expectations for Morocco, given that the percentage of electricity produced by renewable energies has not exceeded 20% in the last decade. In other words, renewable energies have not yet reached a level where they can significantly drive GDP growth in the country.

1. Renewable energy consumption does not cause Morocco's GDP growth
2. Renewable energy consumption is caused by Morocco's GDP

Figure N°5: Causal links between variables

Source: Author

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6. Conclusion

Utilizing annual data spanning from 1990 to 2021, this study meticulously examined the causal relationship between renewable energy consumption and GDP in the Moroccan context. Employing a modified Granger causality test developed by Toda and Yamamoto, our analysis reveals a robust unidirectional causal link running from GDP to renewable energy consumption, thereby substantiating the conservation hypothesis. This finding implies that Morocco, through judicious allocation of its revenues, has the potential to amplify its utilization of renewable energy sources.

In light of these results, we advocate for the implementation of proactive policies aimed at fostering an increased share of renewable energy in the overall energy consumption landscape. Additionally, strategic investments in this sector are imperative to avoid setbacks in achieving pre-established targets and to catalyze renewable energy's transformative role as a driver of economic growth. Furthermore, we underscore the significance of a technological and innovative approach to enhance the efficiency of investments in renewable energies.

Given that leading countries in the renewable energy sector are characterized by technological progress and innovation, it is imperative to intensify efforts in encouraging innovation and technical advancements within this sector. Policymakers should prioritize initiatives that concentrate on cost-effective renewable energy sources and technological approaches capable of competently rivaling fossil fuel-based energy sources. The understanding that policy initiatives must align with the goal of fostering innovation and technological progress is paramount for the sustainable development of the renewable energy sector.

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