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La production des énergies renouvelables, les émissions de CO2 et la croissance économique au Maroc: Une approche ARDL

Renewable energy production, CO2 emissions and economic growth in Morocco: An ARDL Approach

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Résumé:

Cette étude examine les liens de causalité entre la production des énergies renouvelables, les émissions de CO2 et la croissance économique au Maroc entre 1990 et 2015. À cet égard, nous avons opté pour l'approche ARDL et le test de causalité de Toda Yamamoto en incluant d'autres variables à savoir la formation brute du capital fixe et la main d'oeuvre. Les résultats du test de co-intégration révèlent l'existence d'un équilibre à court et à long termes entre les variables. En outre, à court terme, les émissions de CO2, la production d'énergie à partir de sources renouvelables et la main d'oeuvre ont un impact négatif sur le PIB. La formation brute de capital fixe a également un impact négatif sur la croissance économique jusqu'à un an, mais cet impact devient positif après deux ans. À long terme, le PIB est principalement causé par les émissions de CO2, la main d'oeuvre et la production d'énergie à partir de sources renouvelables. Ces résultats soutiennent l'hypothèse de croissance. Le capital n'influence pas directement la croissance économique au Maroc, mais indirectement à travers la production d'énergie.

Mots clés:

Les énergies renouvelables; La croissance économique; Les émissions de CO2; Développement du Maroc; l'approche ARDL

Abstract:

This study examines the causal links between renewable energy production, CO2 emissions, and economic growth in Morocco between 1990 and 2015 by using ARDL approach and Toda Yamamoto's causality test. Capital and labor variables were added to strengthen our model. The results of the co-integration test reveal the existence of a short- and long-term equilibrium between the variables. Moreover, in the short run, CO2 emissions, energy production from renewable sources, and labor have a negative impact on GDP. Gross fixed capital formation has a negative impact as well on economic growth for up to one year, but this impact becomes positive after two years. In the long run, GDP is mainly caused by CO2 emissions, labor and energy production from renewable sources. These results support the growth hypothesis. Capital does not directly influence economic growth in Morocco, but indirectly through energy production.

Keywords:

Renewable electricity; Economic growth; CO2 emissions; Moroccan development; ARDL approach

Introduction

The promotion of renewable energies seems to contribute to the security of energy supply and sustainable development. They are in line with the Kyoto Protocol, which for several countries consists of the reduction of CO_2 emissions.

In Morocco, the import of fossil energy still dominates the energy sector. Primary energy consumption will account for about 90% of total energy consumption in 2017 (62% of oil, 22% of coal and 5% of natural gas).[1] This makes the country very vulnerable to fuel price fluctuations and places it in an unstable situation. (Allouhi, Zamzoum, Islam, Saidur, Kousksou, Jamil & Derouich, 2017; Kousksou, Allouhi, Belattar, Jamil, El Rhafiki, Arid & Zeraouli, 2015).

However, Morocco has great potential for the exploitation of renewable energies, mainly solar and wind power (Kousksou, et al., 2015). This will enable it to solve two problems, namely energy security and climate change issues (Šimelytė, 2020). We have chosen to study the case of Morocco as it is a leader among MENA countries in the deployment of clean energy technologies (Šimelytė, 2020). The favorable development prospects of the renewable energy sector have led Morocco, since 2009, to put in place major energy and climate policies. The country has adopted an ambitious energy strategy taking into account its challenges and based mainly on the development of energy efficiency and capacity building in the regions; especially as energy consumption continues to increase (a 32% increase in energy consumption was recorded between 2007 and 2017). Electricity demand has been growing at an average rate of about 5% per year) and is expected to increase by 7 to 8.5% per year over the next ten years (Kousksou, et al., 2015).

Morocco aims to accelerate its energy transition with the aim of producing 42% of its energy from renewable sources by 2020 and 52% by 2030. The country is also committed to reducing its CO_2 emissions by 17% from its base level by 2030 (Morocco's CO_2 emissions are 1.60 t per capita in 2015, which corresponds to 36% of the world average but remains 58% higher than the African average). Morocco accompanies all these policies by the implementation of a number of legislative, regulatory, and institutional provisions, which constitute a pillar of the strategy.

[1] The International Energy Agency (2019)

The studies that have focused on the case of Morocco and link between renewable energy consumption, economic growth, and CO2 emissions are mainly multi-country studies that focus on the MENA region:

Ben Jebli & Ben Youssef (2013) examine the relationship between renewable fuel consumption and waste, real GDP, and real export volume per capita for 11 MENA countries over the period 1975-2008 using the FMOLS and DOLS estimation approaches and the Granger cointegration test. In the long run, a two-way relationship is established between the consumption of renewable fuels and waste and real GDP. Kahia, Aïssa & Lanouar (2017) agree with the conclusion of Ben Jebli & Ben Youssef (2013) and indicate the existence of a feedback relationship between REC and GDP and between NREC and GDP.

Farhani (2013), in turn, examines for a sample of MENA countries, the effect of clean energy use on carbon emissions using the co-integration methods OLS, FMOLS, DOLS, and the Granger test. In the short term, it has been shown that there is a single causal relationship from renewable energy consumption to CO2 emissions that plays an important role in the reduction of CO2. It should be noted that the author examined the energy impact on economic growth, but it was found to be insignificant.

The study by Charfeddine & Kahia (2019) estimates the same models as Farhani (2013) for MENA countries. Empirical results from the autoregressive model on panel data reveal several findings:

- Consumption of renewable energy has a negative impact on CO2 emissions.
- Consumption of renewable energy has a small positive impact on economic growth.

We note that the results that cover Morocco in the panel studies are conflicting, hence the importance of conducting further research in this direction and focusing on the country's case.

At this stage, it is worth asking:

What is the direction of the causal relationship, if any, between renewable energy consumption and GDP on the one hand and CO2 emissions on the other?

To answer this question, we have broken down the article as follows: The first section examines the literature review, the second section presents data and methodology, the third section presents the findings and finally, the conclusion summarizes the results of the research.

1. Literature review

There is much debate about the interactions between renewable energy, economic growth, and the environment. Since 1978, studies have followed one another while evolving according to the needs of the context. In this section, we will briefly review the studies that have focused on the renewable energy-growth nexus and those that have included the CO2 emissions variable.

1.1. Renewable energy - Economic growth literature

There have been many studies on the link linking green energy to the economic advancement of countries. The main differentiation that emerges from this research is that of the conclusions reached. We retain the hypothesis of growth (The growth assumption means that energy consumption contributes to GDP improvement directly or indirectly), conservation (The conservation assumption means that GDP contributes to the increase in energy consumption), feedback (The feedback hypothesis means that the variables impact and complement each other) and neutrality (The assumption of neutrality means that no significant relationship has been established between the variables). Another possible separation is between studies that deal with one country and those that deal with several countries at the same time.

The variables employed differ depending on the study. In the majority of the studies reviewed, GDP is used to measure economic growth and the variable of all-branch combined renewable energy consumption or production is used for renewables. Concerning the methodologies, the most used ones are VECM - Granger causality, OLS, FMOLS and DOLS methods, and ARDL method.

Among the studies that focus on a single country (Aslan (2016); Bilgili (2015); Fang (2011); Ibrahiem (2015); Lin, Yeh & Chien (2013); Ocal & Aslan (2013); Payne (2011); Rafindadi & Ozturk (2017); Shahbaz, Loganathan, Zeshan & Zaman (2015); Yildirim & Aslane (2012)) several have revealed the growth hypothesis:

Fang (2011) revealed a positive impact of renewable energy consumption on GDP and income in the case of China using the OLS method for the period 1978 - 2008. However, Yildirim & Aslan (2012) reported a positive impact of biomass waste derived on GDP in the United States between 1949 and 2010. It should be noted, that no link has been established with other forms of energy and GDP. Aslan (2016) also revealed a positive impact of biomass consumption on US GDP in the short and long term using the ARDL method.

The conservation hypothesis was supported by Ocal & Aslan (2013) who examined the relationship between renewable energy consumption, GDP, labor, and capital in Turkey from 1990 to 2010. They concluded that GDP has a positive impact on the consumption of renewable energy. Lin, et al. (2013) share the same conclusion for the United States and argue that GDP positively affects the consumption of renewable energy for commercial, transportation, and residential use. However, the consumption of renewable electricity has a mutual impact on GDP. No link has been proven for the other sectors.

The feedback hypothesis is supported by Ibrahiem (2015) for the case of Egypt for which examined the link between renewable electricity consumption and economic growth using the ARDL method for the period 1980-2011. The same hypothesis is supported by Shahbaz et al. (2015) and Rafindadi & Ozturk (2017) who used the ARDL method for Pakistan and Germany, respectively, considering the variables of renewable energy consumption, GDP, labor and capital.

In multi-country studies (Abanda, Ng'ombe , Keivani & Tah (2012); Al-mulali, Fereidouni, Lee & Sab (2013); Apergis & Danuleti (2014); Apergis & Payne (2010); Amri (2017); Apergis & Payne (2011); Alper & Oguz (2016); Bayar & Gavriletea (2019); Bayraktutan, Yilgör & Uçak (2011); Ben Aïssa, Ben Jebli & Ben Youssef (2014); Ben Jebli & Ben Youssef (2013); Bhattacharya, Paramati, Ozturk & Bhattacharya (2016); Bildirici (2013); Bilgili & Ozturk (2015); Chang, Gupta, Inglesi-Lotz, Simo-Kengne Smithers & Trembling (2015); Chien & Hu (2007); Destek (2016); Kula (2013); Hung-Pin (2014); Hamit-Haggar (2016); Halkos & Tzeremes (2014); Inglesi-Lotz (2016); Isik, Dogru & Turk (2018); Ozturk & Bilgili (2015); Ozcan & Ozturk (2019); Sadorsky (2009b); Shahbaz, Rasool, Ahmed & Mahalik (2016); Simionescu, Bilan, Krajňáková, Streimikiene & Gędek (2019)), we also note the emergence of 4 hypotheses:

For Chien & Hu (2007), the use of green energy promotes technical efficiency in the countries examined. The experience of Bilgili & Ozturk (2015) comes to the same conclusion regarding the effect of biomass energy use in the G7 countries using OLS and DOLS methods. Bayar & Gavriletea (2019), based on Westerlund's cointegration, indicated the existence of a positive influence of renewable energy consumption on the energy efficiency of 22 emerging countries from 1992 to 2014. However, Sadorsky (2009b) (18 emerging countries) and Kula (2014) (OECD countries) concluded the conservation assumption that it is economic development that drives the consumption of renewables.

The feedback hypothesis is supported by several studies (Apergis & Payne (2010); Apergis & Payne (2011); Apergis & Danuleti (2014); Amri (2017); Bayraktutan, et al., (2011); Shahbaz, et al., (2016)).

However, Abanda, et al., (2012) who examine in their study the impact of renewable energy production on economic growth in a panel of African countries, conclude using the OLS method that there is no causal link between the variables.

1.2 Renewable energy - Economic growth - CO2 emissions literature

The inclusion of the CO2 emissions variable is the new trend in energy studies. Aware of the new requirements of sustainable development and environmental concerns, researchers and politicians have been studying the analysis of the impact of this new form of energy on gas emissions, making a comparison between renewable and non-renewable energies. Many studies have concluded that CO2 emissions contribute to the increase in renewable energy consumption (Apergis & Payne (2014a); Koengkan, Fuinhas & Marques (2019); Sadorsky (2009a); Salim & Rafik (2012); Sebri & Ben- Salha (2014)).

Sadorsky (2009a) develops an empirical model of renewable energy consumption in G7 countries. The long-term elasticity estimated from the FMOLS model shows that a 1% increase in GDP and carbon emissions increases the consumption of renewable energy by 8.44% and 5.23% respectively. Apergis & Payne (2014a) examine the factors influencing renewable energy consumption in a panel of 11 South American countries over the period 1980-2010 using error-correction models. In the short term, an increase in per capita carbon emissions leads to an increase in per capita consumption of renewable energy, while an increase in per capita consumption of renewable energy leads to a reduction in carbon emissions (Circle). A feedback relationship was also revealed between renewable energy consumption and GDP in the short and long term. Sebri & Ben-Salha (2014) use the ARDL technique and the Granger causality test to examine the relationship between variables for the first time in BRICS countries over the period 1971-2010. The results demonstrate the significant effect of CO2 emissions in promoting the consumption of renewable energy and support the hypothesis of feedback between growth and consumption of renewable energy.

We point out that the majority of the studies reviewed concluded that renewable energies contributes to CO2 reduction (Apergis & Payne (2014b); Bölük & Mert (2015); Ito (2017); Chen & Lei (2018); Charfeddine & Kahia (2019); Farhani (2013); Kulionis (2013); Silva, Soares & Pinho (2011); Tiwari (2011)).

Tiwari (2011) focuses on the case of India during the period 1960-2009 and considers the interactions between the variables of hydropower consumption, GDP, and CO2 emissions through the autoregressive vector methodology. His analysis reveals that a positive shock in hydropower consumption leads to an increase in GDP and a decrease in CO2 emissions (inverse effect in the beginning) and a positive shock in GDP has a high impact on CO2 emissions. Bölük & Mert (2015) analyze the case of Turkey from 1961 to 2010 by considering the production of electricity from renewable energies, CO2 emissions, and GDP. Its results prove that the production of electricity contributes to the reduction of CO2. Ito (2017) analyses data from a panel of 42 developed countries between 2002 and 2011 comparing the effect of renewable and non-renewable energy on CO2 emissions. The results prove that the consumption of renewable energies contributes to the reduction of CO2, and the increase of GDP. Moreover, there is a substitution relationship between the two forms of renewable and non-renewable energy.

Other studies have concluded a feedback link between renewable energy consumption and CO2 emissions (Apergis & Payne (2014b); Ben Mbarek, Saidi & Rahman (2018); Irandoust (2016); Koengkan, et al., (2019)) and between CO2 emissions and non-renewable energy consumption (Asongu et al. (2016); Menegaki (2011)).

Apergis & Payne (2014b) identify the links between the use of renewable energies and other economic and environmental factors in the countries of Central America. The results indicate that there is a reciprocal link between GDP and both the energetic variable and the environmental variable. Koengkan, et al., (2019) examined the links between the variables by including non-renewable energy consumption in a panel of 12 Latin American countries. The results indicate that renewable energy consumption has a mutual impact on CO2 emissions and GDP. Menegaki (2011) also concludes for the case of 27 European countries, the existence of a relationship between CO2 emissions and GDP.

The literature on renewable energy, economic growth, and carbon emissions is abundant. Yet Adewuyi & Awodumi (2017) note that the results are conflicting and paradoxical and depend on several factors, namely the methodology used, the variables mobilized, the region in question, and the period covered.

On the basis of the literature review and taking into account the objective of our research work, we can deduce twelve possible relationships between the variables (Table 1):

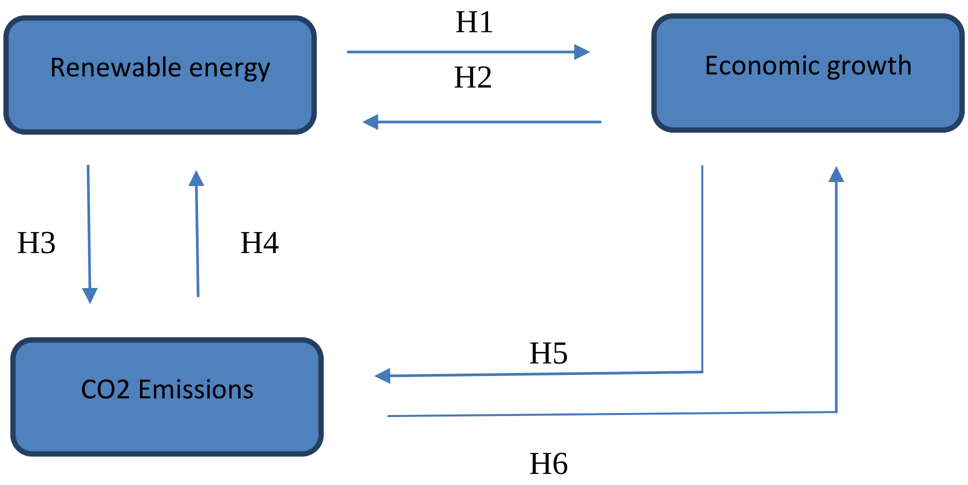
Table 1: Research Hypotheses

RE and CO2	GDP and RE	CO2 and GDP
RE $\longrightarrow$ CO2	GDP $\longrightarrow$ RE	CO2 $\longrightarrow$ GDP
RE $\longleftarrow$ CO2	CO2 $\longleftarrow$ RE	CO2 $\longleftarrow$ GDP
RE $\longleftrightarrow$ CO2	GDP $\longleftrightarrow$ RE	CO2 $\longleftrightarrow$ GDP
RE $\neq$ CO2	GDP $\neq$ RE	CO2 $\neq$ GDP

Source: Authors

All of these elements were used to form our conceptual model, which is as follows (Figure 1):

Figure 1: Research Model



Source: Authors

To test these hypotheses, we will adopt the ARDL approach proposed by Pesaran et al. (2001) and the Toda-Yamamoto causality test.

2. Empirical Analysis

2.1. Data

The data that are the subject of our study relate to Morocco and are annual and drawn from World Bank databases or reports. These annual data cover the period from 1990 to 2015.

The Table 2 below provides the variables used:

Table 2: Variables used in the study

Variables	Definitions	Expected effects
GDP	Growth rate of Morocco's Gross Domestic Product (in %)	
ELECT_PROD	The rate of change in electricity production from renewable sources (%)	+
GFCF	The share of Gross Fixed Capital Formation in GDP (as a % of GDP): this proxy variable for investment	+
CO2_emissions	Carbon dioxide emissions in tons per capita	+
Labor	The share of the labor force in the total population (in %)	+

Source: Authors

2.2. Methodology

The objective of this study is to examine the short and long-term relationships between economic growth (*gdp: dependent variable*) and electricity production from renewable sources (*elect_prod: explanatory variable*), taking into account other essential independent variables whose influence improves the results. These variables are CO2 emissions (*CO2_emissions*), gross fixed capital formation (*gfcf*), and labor (*labor*).

We have opted for the ARDL model which belongs to the class of dynamic models and allows us to capture temporal effects in the explanation of a variable. This approach is interesting in that it allows the integration of variables of different order I(0) or I(1). However, it cannot be used if they are of order 2 I(2). Note that the dependent variable must be of order I(1). This approach also includes the lag length which eliminates problems resulting from endogeneity.

Thus, we propose to estimate an ARDL model for the following function (linear functional form):

Gdp= f (elect_prod; fbcf; labor; CO2_emissions)

If one proposes to capture the short- and long-term effects of the above explanatory variables on economic growth, the ARDL representation of the function will be:

$$\Delta gdp_t = a_0 + \sum_{i=1}^{p} a_{1i}\Delta gdp_{t-i} + \sum_{j=0}^{q} a_{2j}\Delta elect\_prod_{t-j} + \sum_{j=0}^{q} a_{3j}\Delta FBCF_{t-j} + \sum_{j=0}^{q} a_{4j}\Delta labor_{t-j} + \sum_{j=0}^{q} a_{5j}\Delta CO2\_emissions_{t-j} + b_1 gdp_{t-1} + b_2 elect\_prod_{t-1} + b_3 FBCF_{t-1} + b_4 labor_{t-1} + b_5 CO2\_emissions_{t-1} + e_t$$

With: Δ first-difference operator;

a_0: Constant;

$a_1 \ldots a_5$: Short-term effects;

$b_1 \ldots b_5$: Long-term effects;

(e_t): Error term (white noise).

As with any dynamic model, we will use the information criteria (Akaike-AIC and Shwarz-SIC) to determine the optimal shifts (p,q) of the ARDL model.

The estimation of an ARDL model assumes the existence of a cointegrating relationship between the variables, which even conditions the estimation of their short- and long-term coefficients.

When several integrated variables of different orders (I(0), I(1)) are available, the cointegration test of Pesaran et al. (2001) is used. After determining the optimal offsets, the test procedure continues by comparing the Fisher values obtained with the critical values (bounds).

Therefore, estimating an error-correction model can help confirm whether cointegration between variables exists. This model will take the following form for the purposes of our study:

$$\Delta gdp_t = a_0 + \sum_{i=1}^{p} a_{1i}\Delta gdp_{t-i} + \sum_{j=0}^{q} a_{2j}\Delta elect\_prod_{t-j} + \sum_{j=0}^{q} a_{3j}\Delta FBCF_{t-j} + \sum_{j=0}^{q} a_{4j}\Delta labor_{t-j} + \sum_{j=0}^{q} a_{5j}\Delta CO2\_emissions_{t-j} + \boldsymbol{\theta u_{t-1}} + e_t$$

These relationships will be subject to estimates. Thus, the procedure to be followed for this ARDL modelling is described as follows:

- Determine the degree of integration of the variables (stationarity test): Augmented Dickey-Fuller/ADF test;
- Testing the possible existence of a cointegration relationship between variables: cointegration test at the boundaries of Pesaran et al. (2001);

- Testing causality between the variables under study: causality test in the sense of Toda and Yamamoto.

We used the Eviews 10 software for the study of the stationarity of the series, the cointegration test, the causality test and the estimates. This software, adapted for econometric analyses, offers the possibility to run several tests not initially integrated in other versions of the software.

3. Empirical results

3.1. Stationarity of the series

A time series whose moving average or variance varies over time is said to be non-stationary if this non-stationarity (of the deterministic or stochastic type) is not addressed. This can lead to misleading regressions. For this purpose, we used augmented Dickey-Fuller/ADF.

The results are as follows (the calculated statistics are of t of student):

Table 3: Stationarity series tests by ADF test

Variables	Level	Difference 1	Result: Integration order
GDP	-2.22 (0.204)	-10.35** (0,00)	I(1)
ELECT_PROD	-4.25*** (0,003)		I(0)
GFCF	0.21 (0,73)	-4.07*** (0,00)	I(1)
CO2_emissions	2.34 (0,99)	-4.57***(0,00)	I(1)
Labor	2.63 (1,00)	-5.32*** (0,00)	I(1)

Source: Authors *(our estimates on Eviews 10)*

*(.): Probability; ***: 1% stationary; **: 5% stationary*

The results in Table 3 indicate that the series of variation rates of electricity production are stationary at level (without differentiation), while the growth rate of the Moroccan GDP, the gross fixed capital formation, the CO_2 emissions and labor are integrated of order 1 (stationary after the first difference).

The series are thus integrated in different orders, which makes Engle and Granger's and Johansen's cointegration test ineffective, and makes the cointegration test at the bounds appropriate.

3.2. Cointegration test

To apply the Pesaran cointegration test, we will follow two steps:

3.2.1. Optimal offset and estimation of the ARDL model according to the Schwarz criterion (SIC)

We will use the Schwarz Information Criterion (SIC) to select the optimal ARDL model, the one that can provide statistically significant results with the fewest parameters. Below are the estimation results of the optimal ARDL model selected.

Table 4: Optimal model obtained: ARDL (2, 2, 3, 3)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP(-1)	-1.273072	0.208018	-6.119995	0.0017
GDP(-2)	-0.434891	0.219533	-1.980982	0.1044
GFCF	-1.177710	0.466695	-2.523513	0.0529
GFCF(-1)	1.132668	0.352477	3.213454	0.0236
GFCF(-2)	-0.442142	0.273237	-1.618164	0.1666
CO2_EMISSIONS	8.497390	10.74936	0.790502	0.4651
CO2_EMISSIONS(-1)	-28.53911	9.113400	-3.131555	0.0259
CO2_EMISSIONS(-2)	0.881826	6.086119	0.144891	0.8905
CO2_EMISSIONS(-3)	47.85109	9.472752	5.051446	0.0039
LABOR	-1.527267	1.626931	-0.938741	0.3910
LABOR(-1)	1.309541	3.164379	0.413838	0.6961
LABOR(-2)	13.39943	3.483925	3.846075	0.0120
LABOR(-3)	4.785221	2.762086	1.732466	0.1437
ELECT_PROD	-0.028401	0.011390	-2.493547	0.0549
ELECT_PROD(-1)	0.030696	0.009427	3.256152	0.0225
ELECT_PROD(-2)	0.030283	0.010169	2.977992	0.0309
ELECT_PROD(-3)	0.038210	0.010893	3.507725	0.0171
C	-916.8076	129.0225	-7.105794	0.0009
R-squared	0.971676	F-statistic		10.08980
Adjusted R-squared	0.875373	Prob(F-statistic)		0.009020
		Durbin-Watson stat		2.110320

Source: Authors *(our estimates on Eviews 10)*

**Dependent variable: GDP growth rate*

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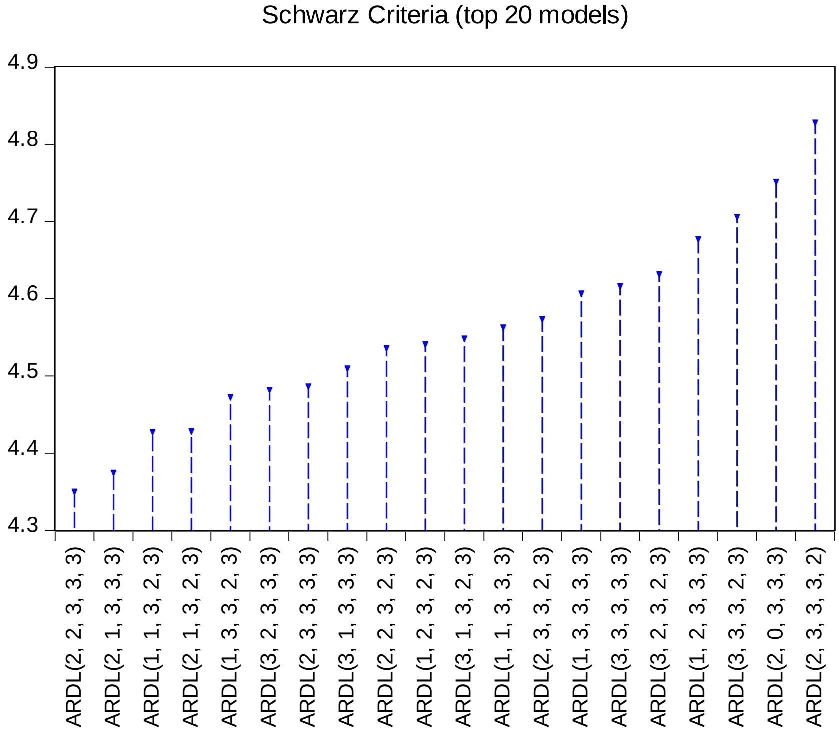
<u>Figure 2:</u> SIC Graphic values



Source: Authors *(our estimates on Eviews 10)*

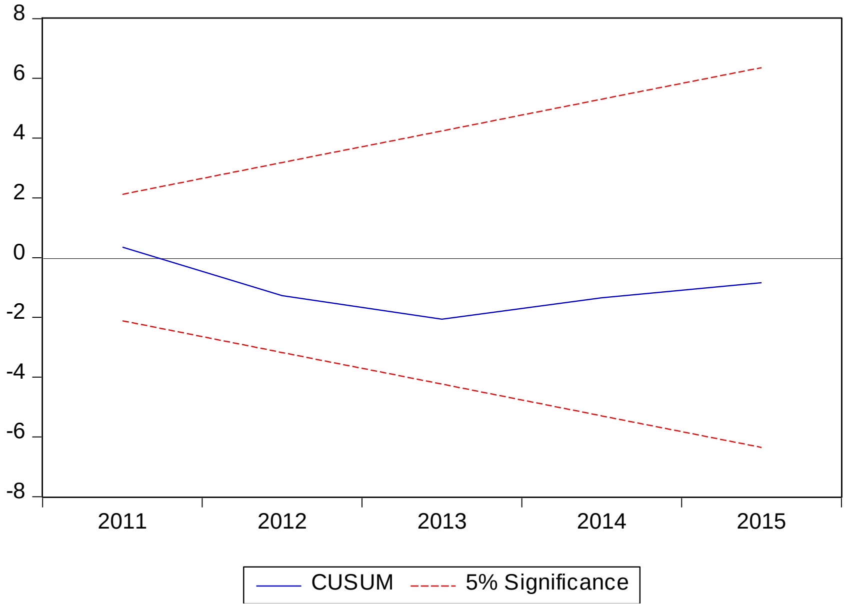
As we can see in the Figure 2, the ARDL model (2,2,3,3) is the most optimal among the 20 others presented, since it offers the lowest Schwarz value. Moreover, with regard to the tests that help to diagnose the estimated ARDL model, we note the absence of autocorrelation of the errors: there is no heteroscedasticity in addition to the normality of the errors. The model has therefore been well specified.

<u>Table 5:</u> Diagnostic test results of the estimated ARDL model

Null hypothesis of the test	Tests	Values (probability)
Lack of autocorrelation of errors	Breusch-Godfrey	1,34 (prob. 0.38)
Homoscedasticity	Breusch-Pagan- Godfrey	2.43 (prob. 0.17)
	Arch-test	1.29 (prob. 0.27)
Error normality	Jarque-Bera	0.05 (prob. 0.98)

Source: Authors *(our estimates on Eviews 10)*

Figure 3: CUSUM stability test results



Source: Authors *(Our estimates on Eviews 10)*

The null hypothesis is accepted for all these tests. Our model is thus statistically valid. The estimated ARDL (2,2,3,3) model is globally good and explains at 97.1% the GDP growth in Morocco from 1990 to 2015.

3.2.2. Cointegration test at the terminals by the Fisher F test

Following the automatic procedure on Eviews 10, the cointegration test of Pesaran et al. (2001) requires that the ARDL model be estimated beforehand. The calculated test statistic, the Fisher F-value, will be compared to the critical values (which form bounds) as follows:

Table 6: Results of the cointegration test of Pesaran et al. (2001)

Variables	GDP; elect_prod; GFCF; CO2_emissions; Labor	
F-stat calculated	13.909	
Critical threshold	Lower terminal I(0)	Top terminal I(1)
1%	3.29	4.37
5%	2.56	3.49
10%	2.2	3.09

Source: Authors *(our estimates on Eviews 10)*

The results of the cointegration bounds test confirm the existence of a cointegrating relationship between the series under study (the value of F-stat (13.909) is significantly higher than that of the upper bound (4.37)), which provides an opportunity to estimate the long-term effects of elect_prod; GFCF; CO2_emissions; Labor on GDP.

First, we are interested in the causality between variables, including the causal elements of the following variables: gdp, elect_prod and CO2_emissions.

3.3. Short- and long-term relationship

3.3.1 Short-term coefficients

First of all, the Table 7 below shows an adjustment coefficient or recall force that is statistically significant and negative (-2.70), which guarantees an error correction mechanism and thus the existence of a long-term relationship (cointegration) between variables.

Table 7: Results of estimation of TC coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GDP(-1))	0.434891	0.113395	3.835189	0.0122
D(GFCF)	-1.177710	0.180757	-6.515443	0.0013
D(GFCF(-1))	0.442142	0.188887	2.340771	0.0663
D(CO2_EMISSIONS)	8.497390	4.931937	1.722931	0.1455
D(CO2_EMISSIONS(-1))	-48.73292	5.081921	-9.589469	0.0002
D(CO2_EMISSIONS(-2))	-47.85109	4.890943	-9.783613	0.0002
D(ELECT_PROD)	-0.028401	0.007613	-3.730531	0.0136
D(ELECT_PROD(-1))	-0.068494	0.008492	-8.065477	0.0005
D(ELECT_PROD(-2))	-0.038210	0.008235	-4.640245	0.0056
D(LABOR)	-1.527267	0.828703	-1.842961	0.1247
D(LABOR(-1))	-18.18466	2.080492	-8.740557	0.0003
D(LABOR(-2))	-4.785221	1.558218	-3.070958	0.0278
CointEq(-1)*	-2.707962	0.209605	-12.91934	0.0000

Source: Authors *(our estimates on Eviews 10)*

**Dependent variable: GDP growth rate*

Similarly, we note the following:

- Instantaneous negative short-term effect of CO2 emissions on GDP; an increase in CO2 emissions in tons per capita generates a decrease in growth in the short term;

-Instantaneous negative effect of electricity generation on GDP; an increase in electricity generation from renewable sources leads to a decrease in growth in the short term;

- A short-term negative instantaneous effect of the labor force on GDP; thus an increase in the share of the labor force in the country's demographic structure may slow economic growth in the short term;
- GFCF has a negative effect on GDP growth over a one-year period, but after two years this effect reverses and becomes positive. The importance of the time dimension of the effects on economic growth leads us to focus more on the analysis of long-term effects.

3.3.2 Long-term coefficients

The Table 8 below provides us with the estimated long-term coefficients or elasticities. In contrast to the short term, the long-term effects on economic growth in Morocco are reversed and become positive. These effects are rather more significant (Prob. < 0.05 and positive coefficients). Thus, we note that any increase in the production of electricity from renewable sources can significantly and positively accelerate growth in Morocco in the long term. Similarly, we note that CO_2 emissions have positive effects on national GDP growth in the long term.

Table 8: Results of estimation of LT coefficients /Long term equation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GFCF	-0.179908	0.192802	-0.933123	0.3936
CO2_EMISSIONS	10.59512	2.671346	3.966211	0.0107
ELECT_PROD	0.026141	0.008551	3.057130	0.0282
LABOR	6.634852	1.005732	6.597034	0.0012
C	-338.5599	51.45049	-6.580305	0.0012

EC = GDP - (-0.1799*FBCF + 10.5951*CO2_EMISSIONS + 0.0261*ELECT_PROD + 6.6349 *LABOR -338.5599)

Source: Authors *(our estimates on Eviews 10)*

**Dependent variable: GDP growth rate*

3.4. Causality tests (Toda-Yamamoto)

When non-stationary variables are not cointegrated or are integrated at different orders, the traditional Granger causality test becomes ineffective. In this case, the causality test in the sense of Toda-Yamamoto (1995), which is based on Wald's "W" statistic, is used. This one is distributed according to a chi-square. The null hypothesis stipulates the absence of causality between variables (probability > 5%).

Table 9: Toda-Yamamoto Causality Test Results

Dependent Variables (DV)	Explanatory or causal variables/VC (probability)				
	GDP	Elct_prod	CO2_emissions	LABOR	GFCF
GDP	--	10.70*** (0,01)	16.18*** (0,001)	18.38*** (0,0004)	2.57 (0,46)
ELECT_PROD	5.82 (0,12)	--	3.91 (0,27)	2.74 (0,43)	8.05** (0,04)
CO2_EMISSION	0.62 (0,89)	0.02 (0,99)	--	6.81* (0,08)	0.72 (0,87)

Source: Authors *(our estimates on Eviews 10)*

*( ) Probabilities (p-value); ***: significant at 1%; **: significant at 5%; *: significant at 10%; values = de Toda-Yamamoto's WALD statistics*

From the Table 9, we deduce the following unidirectional causalities in the sense of Toda-Yamamoto:

- Morocco's GDP growth is mainly caused by labor, CO2 emissions and electricity production from renewable sources.
- Electricity generation from renewable sources is caused by gross fixed capital formation (proxy of investment).
- CO2 emissions are caused (slightly) by labor.

Conclusion

This study examines the causal links between electricity production from renewable sources, CO_2 emissions, and economic growth in Morocco from 1990 to 2015. The ARDL approach is used to examine the short- and long-term relationships between the variables (REP, GDP, CO_2 emissions, CAP, LAB).

The results reveal that in the short term, renewable energies, carbon emissions, and the labor force have a negative impact on GDP. Gross fixed capital formation also has a negative impact on economic growth for up to one year but becomes positive after two years. In the long term, GDP is positively impacted mainly by CO_2 emissions, the labor force and electricity generation from renewable sources. These results support the growth hypothesis. GFCF does not directly influence economic growth in Morocco, but indirectly through electricity production to explain the dynamics of GDP.

Our findings suggest that policy makers in Morocco should increase their efforts on investment in the development of the renewable energy sector in order to enhance energy autonomy and generate sustainable economic growth. One of the major challenges currently facing Morocco is that of the transition from a simple production and consumption of renewable electricity at the local level to an energy economy. Several issues need to be addressed, including those related to energy storage and the integration of renewable energy into the electricity grid, especially as Morocco has become a net exporter of renewable electricity to Algeria and Spain since 2019.

A transformation of production and consumption systems is necessary to switch to sustainable and clean energy. Morocco is also required to offer an attractive investment climate and strengthen public-private collaboration. Note that Lam’hammdi & Makhtari (2018) insists that foreign investment in Morocco is strongly influenced by the variables of gross fixed capital formation and labor force.

In parallel with the implementation of new renewable energy systems in Morocco, it is also necessary to promote the expansion of the renewable energy market by implementing consumption incentives (exemptions, reduced tariffs, subsidies, etc.) as well as taxes on fossil fuels.

On the managerial level, energy management is not easy to implement within a company and several challenges are to be met. The type of organization, its culture, context, and stakeholders are all factors to be considered when choosing a good small-scale management method. Luu (2017) argues that the reactive and iterative approach shows promise in this direction and promotes continuous improvement of the energy project management process. Taking organizational change into account is a key element in bringing theory and practice closer together.

Morocco must attach particular importance to energy efficiency assessment projects. It is strongly recommended that companies set up a dashboard that includes the environmental and social variables in order to move towards a convergence of objectives.

Despite all the care taken in the elaboration of this research work, some limitations must be mentioned. We note, firstly, the limit on the number of observations in this study, which is 15 studies. This number is correct, but it is preferable in this type of work to address a larger number, which is not possible in our case since renewable energies have only been considered from the year 1990 onward. Furthermore, this study focuses on the case of a single country, which implies that the results should not be generalized beyond its borders: Each region should be examined in such a way as to take into account its context and its main characteristics.

Future research may also look into the use of new research methodologies to examine these links or to compare the respective impacts of both renewable and fossil fuels in Morocco. The inclusion of fiscal and monetary policies undertaken by Morocco in the examination of these links is also an interesting avenue.

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