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RESEARCH ARTICLE

Economic growth, trade openness and renewable energy: An empirical investigation of the environmental Kuznets curve in Morocco

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ABSTRACT

In recent years, Morocco has begun to deploy renewable energies, particularly solar and wind power. This article therefore analyzes the role of renewable energies in reducing CO2 emissions, as part of an analysis of the validity of the Kuznets environmental curve hypothesis. We will therefore study the impact of economic growth on the environment, and in particular on carbon dioxide emissions, by introducing other explanatory variables, namely renewable electricity production and trade openness, over the period 1990-2017. We will empirically test the causality between the variables and the validity of the Kuznets environmental curve hypothesis for the Moroccan case, using the Autoregressive Staggered Lag Model approach and the Granger causality test. Indeed, few empirical studies have investigated the validity of the Kuznets environmental curve in Morocco, and none have examined the potential of renewable energies in this respect. Our results suggest that there is a strong cointegration between our variables and that economic growth can be achieved in parallel with environmental policies aimed at limiting CO2 emissions. The role of renewable energies in limiting CO2 emissions has been demonstrated, but the Kuznets environmental curve hypothesis for the Moroccan case has not been confirmed.

INTRODUCTION

Today, in the interests of sustainability, economic growth cannot be detached from the issue of environmental deterioration, and must be achieved with due consideration for its various repercussions on the environment. However, opinions differ as to whether economic growth and environmental protection can go hand in hand. Zero-growth advocates see the environment as a brake on economic growth, while green-growth advocates argue that it is possible to achieve economic growth while preserving the environment. The theory of the Environmental Kuznets Curve (EKC) therefore supports the arguments of green growth advocates, since it asserts that economic growth, once it reaches a certain level, would enable the environment to be preserved. The EKC hypothesis postulates that the relationship between economic growth and environmental degradation follows an inverted U-shaped curve. This suggests that once a certain level of gross domestic product (GDP) per capita has been exceeded, the increase in environmental degradation is reversed, so that a higher GDP per capita leads to environmental restoration, reversing the damage suffered during the initial stages of growth. One of today's major environmental concerns is global warming caused by the accumulation of greenhouse gases. Indeed, the energy sector, based on the consumption of fossil fuels, is the main cause of these gases, and in recent years has undergone structural changes in terms of energy efficiency and the introduction of renewable energies. The Kingdom of Morocco, a North African country located on the Atlantic and

Mediterranean coasts, is a country rich in geography, diversity and openness to trade. In recent years, Morocco has embarked on an energy strategy aimed at deploying renewable energies. Indeed, the country has been experiencing growing energy demand for years, and is obliged to meet this demand by importing energy, given its lack of conventional energy resources. Its interest in deploying renewable energies is therefore motivated by several factors. The main aim of this new strategy is not only to help reduce greenhouse gas emissions and meet international commitments in terms of environmental protection, but also to reduce energy dependency by stimulating local production of clean energies, ensure energy security and provide widespread access to energy in rural areas. Morocco's economic growth is mainly volatile. This volatility is linked to the concentration of production in a small number of sectors, namely raw materials and agriculture, which are highly dependent on world markets and climatic hazards. The aim of this paper is therefore to provide empirical results on the feasibility of green growth in Morocco, by studying the validity of the Kuznets environmental curve and highlighting the role of renewable energies in this respect. To this end, this paper will first present an overview of the Moroccan context. We will then present a brief review of the literature, followed by the methodology adopted. Finally, the empirical results are presented and analyzed.

LITERATURE REVIEW AND DEVELOPMENT OF HYPOTHESES:

The concept of green growth

In order to achieve its growth objectives, the world has drawn on its resources and, at the same time, caused enormous damage to its environment. Indeed, in the early 1970s and 1980s, the Club of Rome's "Stop Growth" report denounced the gravity of the global situation and sounded the alarm about the consequences of industrialization and the exponential growth model on which the system was based. It was from this observation that the concept of sustainable development emerged. The need to find an economic model that takes account of the environmental and social dimensions became obvious. Today, environmental protection policies are often seen as an obstacle to economic growth, and their impact on the economy has been questioned. Indeed, the need to meet the dual challenge of expanding economic opportunities and protecting the environment has led to the emergence of the concept of "green growth".

Considered as a practical approach to implementing sustainable development, the concept of green growth means, according to the OECD, "Promoting economic growth and development while ensuring that natural assets continue to provide the environmental resources and services on which our well-being depends". This means taking advantage of environmental policies to boost the economy and liberalize new growth drivers. Indeed, the simplest definition of green growth would be economic growth (gross domestic product growth) while scientifically protecting the environment. The World Bank defined it in 2012 as: "Growth that uses its natural resources efficiently, it is clean growth that does not pollute and minimizes impacts on the environment, it is also resilient growth that represents the role of environmental and natural capital management to prevent physical disasters". The UNDP's Green Economy report also clarified the concept of green growth, confirming that environmental protection entails costs in the short term, but that these investments will generate growth in the medium and long term. The concept of green growth is therefore not new. At the heart of the sustainable development discourse, it is seen as a means of achieving sustainable development. (World Bank, OECD, UNEP). Green growth argues that economic growth is not only compatible with environmental protection, but can also generate and be the source of better growth. Green growth relies on investment and innovation to achieve its goals. This obviously involves investment in environmental protection, leading to the creation of so-called "green jobs", and culminating in the creation of green industries, which create added value. As these concepts emerge, a recent theory has provided an essential foundation for the plausibility of green growth. This is the hypothesis of the environmental Kuznets curve.

Develop hypotheses

Initially, the Kuznets curve illustrated empirical observations of the evolution of inequalities in the distribution of income and wealth and of economic growth. Kuznets (1955) studied the impact of the industrial revolution in the United States during the 19th and 20th centuries on the distribution of wealth. These empirical observations enabled him to draw an inverted U-shaped diagram of this

evolution, leading to the conclusion that economic growth would reduce inequality in income distribution. However, this relationship has been controversial because of its inapplicability in a general context. Its validity has been questioned in some countries, notably in the developing world. Despite these challenges, the Kuznets curve was transposed to the environmental field by replacing the vertical axis previously used as a statistical indicator of social inequality with an indicator of pollution. This transposition gave rise to what is now known as the Environmental Kuznets Curve. The EKC hypothesis postulates that the relationship between economic growth and environmental degradation follows an inverted U-shaped curve. This suggests that economic growth would initially cause environmental deterioration.

However, once a certain level of Gross Domestic Product (GDP) per capita, the increase in environmental degradation is reserved, so that a higher GDP per capita leads to environmental restoration, enabling the damage suffered during the early stages of growth to be reversed. We will therefore attempt to test the feasibility of green growth in Morocco by studying the validity of the Kuznets environmental curve and empirically testing our Hypothesis 1: which maintains that economic growth in Morocco, once it has reached a certain level of development, would enable CO2 emissions to be reduced and thus protect the environment. On the other hand, one of the major concerns of environmental polices is global warming

The energy sector, based on the consumption of fossil fuels, is the main cause of these gases, and has therefore been undergoing structural changes in recent years in terms of energy efficiency and the introduction of renewable energies into the global energy mix. Long regarded as alternative energies, renewable energies are now enjoying great success thanks to their inexhaustible, environmentally-friendly nature. The impact of these clean energy sources on reducing CO2 emissions and protecting the environment should not be overlooked. Indeed, in order to gain a clearer understanding of this issue, a number of researchers have taken an empirical look at the validity of the relationship between pollution and economic growth in different contexts, taking into account the role that renewable energies can play in this respect, and integrating explanatory variables such as renewable energy consumption and renewable electricity production into their models. (Jebli et al. (2016); Boluk, Mert (2016); Ben Jebli, Ben Youssed (2015); Bilgili, Kocak, Bulut (2016); Sinha, Shahbaz (2018))

We will therefore attempt to study the impact of renewable energies on CO2 emissions in Morocco, testing our Hypothesis 2, which maintains that the production of electricity from renewable sources would reduce CO2 emissions and thus contribute to environmental protection.

LITERATURE REVIEW

Early research to test the validity of the Kuznets environmental curve studied the relationship between CO2 emissions and economic growth, represented by GDP/capita. Recently, several explanatory variables have been incorporated into the basic model, such as international trade (Al-Mulali et al. (2016); Jebli et al. (2016)), represented by trade openness and considered an important factor in pollution. Some researchers have also considered that human capital represents an important variable to integrate (Mahmood, Wang, Hassan (2019)). But the studies of particular interest to us are those that have investigated the role of renewable energies within the framework of the Kuznets environmental curve hypothesis.

Studies that have analyzed the Kuznets environmental curve hypothesis can be divided into two categories. The first concerns studies carried out on panel data, while the second concerns studies carried out on time series. Some researchers have therefore focused on studying the validity of the Kuznets environmental curve on a group of countries. The research of Shafik and Bandyopadhyay (1992) and Grossman and Kruger (1993, 1995) are considered the pioneering studies in the field, and several researchers continue to be interested in the issue. Bilgili et al (2016), for example, attempted to test the validity of the Kuznets environmental curve on a panel of 17 OECD countries using the FMOLS and DOLS method and data from the period 1977-2010. The authors also set out to determine the role of renewable energy consumption on CO2 emissions, again within the framework of the Kuznets environmental curve hypothesis. The results of the study validate the Kuznets environmental curve hypothesis for the panel and confirm the role of renewable energies in reducing CO2 emissions. Ben Jebli et al (2016) also focused their panel data study on a group of

25 OECD countries for a period from 1980 to 2010. The authors performed a Granger causality test and also used the FMOLS and DOLS method, incorporating GDP, renewable and non-renewable energy consumption and international trade as explanatory variables. The results of the study confirmed the validity of the Kuznets environmental curve for the panel and argue that renewable energy consumption contributes to the increase in CO2 emissions, while renewable energy consumption and international trade help to reduce them. Zoundi (2017) focuses on the African case, studying data from a panel of 25 African countries for the period 1980-2012. The Kuznets environmental curve hypothesis was not confirmed, while the role of renewable energies in limiting CO2 emissions was endorsed by the results of the study. Other researchers have used time series analysis to investigate the validity of the Kuznets environmental curve and the role of renewable energies in limiting CO2 emissions, focusing on specific countries. Boluk and Mert (2016), for example, tested the validity of the Kuznets environmental curve hypothesis and investigated the potential of renewable energies in reducing greenhouse gas emissions in Turkey. The authors used the ARDL approach on data from 1961 to 2010 to determine the relationship between CO2 emissions, GDP and renewable electricity production. The results of the study demonstrated that renewable electricity generation contributes to environmental improvement with a lag of one year, and the authors confirm the potential and importance of renewable energy sources in controlling emissions in Turkey. The Kuznets environmental curve hypothesis was also confirmed. Indeed, the results showed that after reaching a threshold, also known as a GDP/capita peak, of 9920 US Dollars, CO2 emissions begin to fall. Ben jebli and Ben Youssef (2015) also used the ARDL approach and Granger's causality approach to test the validity of the Kuznets environmental curve hypothesis for Tunisia. The authors studied the relationship between CO2 emissions per capita, GDP, energy consumption from renewable and non-renewable sources, and international trade over the period from 1980 to 2009. The results of the study showed that Tunisia has not yet reached the level of GDP per capita required to validate the Kuznets environmental curve, and that over the long term, non-renewable energies and international trade had a positive impact on the rate of CO2 emissions, while renewable energies represent a small but negative impact on the rate of CO2 emissions, for a model with exports. Indeed, this impact is no longer significant when it comes to a model with imports. Dong et al (2018) examined the validity of the Kuznets environmental curve for the Chinese case and investigated the potential of renewable and nuclear energy in mitigating CO2 emissions over a period from 1993 to 2016. To this end, the authors used the ARDL approach to determine the Co-integration relationship between the variables, as well as three estimation techniques, namely: FMOLS, DOLS and CCR, followed by the Granger causality approach. The results of the paper proved the validity of the Kuznets environmental curve hypothesis for the case of China, and determined the curve's peak GDP/capita at 96,680.47 yuan, which the authors estimate will be reached in 2028. The results of the ARDL test also confirmed that the consumption of fossil fuels contributes to CO2 emissions, while the consumption of renewable and nuclear energy sources would improve environmental quality by reducing these emissions. Mahmood et al. (2019) studied the Pakistani case, including as an explanatory variable alongside consumption of renewable energies, international trade and human capital. The study covers the period from 1980 to 2014, and confirms the validity of the Kuznets environmental curve. The authors demonstrated that, unlike non -renewable energy and international trade, renewable energy and human capital reduced environmental pressure by limiting CO2 emissions. Using the ARDL approach, Sinha and Shahabz (2017) studied the validity of the Kuznets environmental curve for the Indian case over a period from 1971 to 2015 , and investigated the potential of renewable energies in reducing greenhouse gas emissions. The authors included international trade, factors of production and energy consumption as explanatory variables, and used the unit root test as an empirical methodology. The results of the study demonstrated the validity of the Kuznets environmental curve hypothesis for the Indian case and estimated the GDP/capita PIC at 2937.77 USD, which is outside the period studied. Sugiawan and Managi (2016) looked at the Indonesian case over a period from 1971 to 2010, taking into account the role of renewables in electricity generation and using the ARDL approach. The results demonstrated the validity of the Kuznets environmental curve for Indonesia, with a peak GDP/capita estimated at 7729 USD, and confirmed the benefits of renewable energies in protecting the environment by limiting CO2 emissions. Concerning the Moroccan case, and to the best of our knowledge, there are few empirical studies to have investigated the validity of the Kuznets

environmental curve in Morocco, and none have examined the potential of renewable energies in this sense. Ul Haq et al (2016) examined the relationship between income, CO2 emissions, energy consumption and trade openness for a period from 1971 to 2011 using Johansen's Co-integration test. The results of the study confirmed the role of energy consumption in environmental deterioration, in contrast to foreign trade, which was found to be beneficial for the latter. However, the Kuznets "environmental curve" hypothesis was not confirmed. Berahab (2017) also studied the Moroccan case for the period 1971-2014, using the ARDL approach and including energy consumption and international trade as explanatory variables. The results of the analysis confirm the existence of a positive long-term relationship between CO2 emissions and GDP. According to Granger causality tests, the direction of the relationship runs from economic growth to CO2 emissions, meaning that it is economic growth that determines the level of emissions, and not vice versa. An environmentally-friendly energy policy can therefore be implemented without adversely affecting economic growth. As for the results of the ARDL test, they validate the Kuznets environmental curve hypothesis.

RESEARCH METHODOLOGY

This paper follows the methodology of recent research carried out on the Kuznets environmental hypothesis and studies the relationship between "economic growth and environmental pollution", also integrating the production of electricity from renewable sources and foreign trade as explanatory variables. The most familiar cointegration tests have been proposed by Engle and Granger (1987), Stock & Watson (1988), not forgetting the multivariate method of Johansen (1988) and developed by Johansen et al. (1991). The aim of this study is to examine the relationship between CO2 emissions, economic growth, renewable electricity production and trade openness, using the Autoregressive Distributed Lag (ARDL) approach introduced by Pesaran and Smith (1998) and further developed by Pesaran, Shin and Smith (2001). Compared with other cointegration tests, the ARDL method is distinguished by the fact that it can be applied to non-transparent time series without the constraint of the same order of the integration. The cointegration test can be performed simultaneously on the integrated variables of order 1 (I (1)) and on the integrated variables on order 0 (I (0)). Another Advantage of the ARDL model concerns sample size. Indeed, this model is better suited to small samples, and gives more reliable results in these cases, compared with other tests.

The general form of the ARDL approach to the equations to be estimated is as follows:

$$\begin{cases} (1)\ DY_{i,t} = \beta_{i,0} + \sum_{i=1}^{P} \beta_{1i} DY_{i,t-i} + \sum_{i=0}^{r} \beta_{2i} X_{t-i} + \varphi_{i,1} Y_{i,t-1} + \varphi_{i,2} X_{t-1} + \varepsilon_{i,1t} \\ DY_{i,t} = \sum_{i=1}^{P} \beta_{1i} DY_{i,t-i} + \sum_{i=0}^{r} \beta_{2i} X_{t-i} + \mu_1 ECT_{i,t-1} + \varepsilon_{i,2t} \end{cases}$$

The variables $Y_{i,t}$ (i = 1,2,3) denote the dependent variables, respectively. The parameters $\varepsilon_{i,1et}$ $\varepsilon_{i,2}$ reflect the residuals of each equation. The β_i denote the constants of each equation. D is the first difference operator and (p, r) represent the number of lags.

In fact, our ARDL analysis follows four steps: The first examines the stationary properties of each variable, using the unit root test to define the order ofintegration of the variables. The Augmented Dickey Fuller (ADF) and Phillips Perron (PP) stationarity tests are used for this purpose. The second step is to verify the existence of long-term relationships between variables, using the Bound Test ARDL approach; the third is to estimate short- and long-term parameters and test model stability; while the fourth is to define the direction of causality between variables, using the Granger causality test.

SEARCH MODEL

In order to test the long-term relationship, also known as cointegration, between CO2 emissions, economic growth, renewable electricity production and foreign trade, and to assess the validity of the Kuznets environmental curve hypothesis for the Moroccan case, the following linear logarithmic form is proposed:

$LCO2t = \alpha + \beta 1\ LPIB + \beta 2\ LPIB^2 + \beta 3\ LOC + \beta 4\ LER + \varepsilon t$

Where: LCO2 represents CO2 emissions per capita, GDP represents real GDP per capita, GDP^2: real GDP per capita squared, OC: trade openness ratio which is used as a proxy for international trade, εt: error term, RE: electricity generation from renewable sources, βi : Parameters represent the long-term elasticity of CO2 emissions.

Study area and description

Our study focuses on Morocco. In 1992, Morocco signed the United Nations Framework Convention on Climate Change at the Earth Summit in Rio de Janeiro, and in 2002 it acceded to the Kyoto Protocol, not forgetting its numerous relevant conventions, such as the Convention for the Protection of the Ozone Layer. To honor its international commitments, Morocco has undertaken a number of political, institutional, legal and socio-economic reforms. The adoption of the National Charter for the Environment and Sustainable Development in 2009, following directives from His Majesty King Mohammed VI, is the greatest proof of this. Indeed, an environmental upgrading strategy has been put in place alongside the national human development initiative and the national sustainable development strategy. Despite its low greenhouse gas emissions, Morocco has taken preventive measures to protect its natural, social and economic environment. Launched as part of a sustainable development program, one of the country's current priorities, alongside the fight against poverty, unemployment and social disparities, is the fight against climate change and the protection of the environment and natural resources. With this in mind, Morocco continues to support international efforts to protect the environment, and has launched its national strategy to combat climate change, which includes measures to mitigate greenhouse gas emissions by integrating clean technologies into its production methods and aiming to establish a low-carbon, green economy. GHG emissions in Morocco are mainly due to the energy sector and the consumption of fossil fuels. For this reason, climate change mitigation measures focus primarily on the energy sector in terms of energy efficiency and the deployment of renewable energies. Indeed, according to the IEA, Morocco's GHG emissions from fuel use are estimated at around 50.5 Mt of CO2 in 2016, and are set to rise rapidly. This increase is mainly due to growth in the residential and energy sectors.

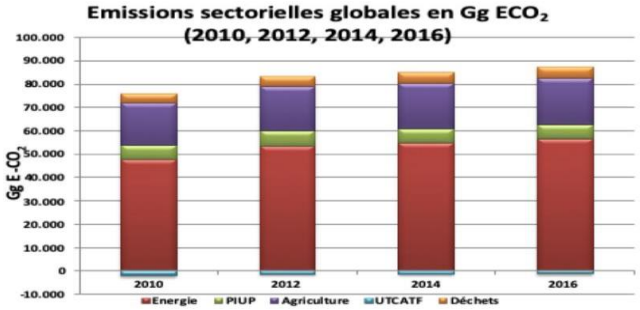

Figure 1: Change in CO2 emissions by sector between 2010 and 2016

Source: UNFCCC report

On the other hand, Morocco's energy needs have been rising for years, as economic growth, sectoral strategies, household consumption and rural electrification have made energy an urgent necessity. Electricity consumption doubled between 1999 and 2015, and final energy consumption reached 16.1 Mtoe in 2017, 34% more than in 2007. According to the HCP, Morocco's population growth and economic expansion mean that the country's energy demand is rising by around 7% a year. Three sectors dominate energy consumption. Transport accounts for 36%, construction for 25% and industry for 24% of final energy consumption. Morocco's energy mix is made up mainly of fossil fuels, which account for almost 90% of primary energy consumption. In 2017, oil accounted for 62% of total primary energy consumption, followed by coal (22%) and natural gas (5%). However, as Morocco has neither oil nor coal sources, and produces only a small amount of gas, its energy supply depends mainly on the external market and energy imports. Indeed, according to ONEE, in 2017, 93.6% of the energy consumed was imported. With an energy bill exceeding 69,500 MDH in 2018, Morocco is widening its trade deficit in order to meet its growing energy demand. Indeed, the trade balance for energy products has worsened significantly, rising

from DH67.3 billion in 2017 to DH78.9 billion in 2018. Electricity imports have also risen by 73% over the past decade to cope with peaks in demand. With a trade deficit of 205.9 billion DH, or 18.5% of GDP in 2018, Morocco's trade balance is heavily impacted by the level of imports. This heavy dependence on fossil fuel imports has prompted the government to reduce imports and opt for renewable energy sources, as well as to launch energy efficiency policies to cope with increased demand in a growing economy. To this end, a national energy strategy was launched in 2009 to ensure an effective energy transition, with four main objectives. First and foremost, it aims to establish energy security by limiting dependence on imported energy. It also aims to reduce carbon emissions and protect the environment, as well as providing widespread access to competitively priced energy and diversifying and optimizing the energy mix through the deployment of renewable energies. The strategy also places energy efficiency at the heart of national priorities, in order to control growing demand. The national energy strategy aims to increase the share of renewable energies from 42% of installed capacity in 2020 to 52% in 2030. Indeed, some 40 billion dollars have been earmarked for the Moroccan energy sector between 2016 and 2030 to develop a capacity of 10100 MW, including 4560 MW of solar energy, 4200 MW of wind energy and 1330 MW of hydraulic energy. It also aims to reduce greenhouse gas emissions by 32% by 2030. Indeed, the share of renewable energies in the electricity mix reached around 35% in 2018.

4. RESULTS AND DISCUSSION

4.1. Results

Before performing the Bound Test, the ARDL model first examines the unit root test, which defines the order of integration of the variables, i.e. those at level I(0) and those at level I(1). Indeed, the ARDL model only concerns series of integration levels 0 and 1, and cannot be performed on series of order 2. To determine the order of integration of our time series, our study uses the Augmented Dickey Fuller (ADF) and Phillips Perron (PP) stationarity tests, the results of which are presented in Table (1) below. The results indicate that most of the variables are stationary in 1st difference, and their evolution fluctuates around several averages. Some are therefore integrated of order (1), others of order 0. However, none of them is integrated of order 2. It is therefore possible to use the ARDL model. The second step is to select the optimal delay number for the vector autoregression. Thanks to information criteria such as the Akaike criterion (AIC), Schwarz criterion (SC), or Hannan and Quinn criterion (HQ). Four VAR models (P = 0, 1, 2, 3) were estimated for the period 1990-2017. The AIC selection criterion for the optimal model lag is equal to 1, which will be used in our study.

Table 1: Results of the ADF and PP stationarity test

	ADF (% 5)		**Phillips-Perron (% 5)**		
Variable	**Level (Intercept)**	**1st. Difference (Intercept)**	**Level (Intercept)**	**1st. Difference (Intercept)**	**Level**
LCO2	-1.038792 (-2.976263)	-5.500046 (-2.981038)	-1.065012 (-2.976263)	-5.521014 (-2.981038)	I (1)
LER	-3.014576 (-2.976263)	-4.430340 (-3.004861)	-3.014576 (-2.976263)	-5.994619 (-2.981038)	I (0)
LOC	_-0.634504 (-2.976263)	-3.519727 (-3.587527)	-0.293120 (-2.976263)	-7.607582 (-2.981038)	I (1)
LPIB	-0.626385 (-2.976263)	-4.398295 (-2.981038)	-0.626385 (-2.976263)	-4.398295 (-2.981038)	I (1)
LPIB Carré	-0.626385 (-2.976263)	-4.398295 (-2.981038)	-0.626385 (-2.976263)	-4.398295 (-2.981038)	I (1)

The significance level is 5% (i.e. 0.05).

Source: Authors

Table 2: ***Statistics and choice criteria for selecting the optimal model delay***

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-305.0088	NA	640092.2	24.72070	24.91573	24.77480
1	-235.4529	111.2895 *	9014.425 *	20.43623 *	21.41133 *	20.70668 *
2	-223.0636	15.85829	13475.99	20.72509	22.48027	21.21190
3	-206.9827	15.43765	18358.08	20.71862	23.25388	21.42179

Source : *Authors*

After determining the order of integration of the different variables and the optimal lag of the model, we use the ARDL or Black Box approach for cointegration to determine the long-term relationship between the variables. The "Bound Test" is used to calculate an F-statistic (Table 3). This tests the null hypothesis, which implies no cointegration H0: 1 = 2 = 3 = 0, against the alternative hypothesis, H1: 1≠2≠3≠0, which implies the existence of a long-term relationship between the variables studied.

Table 3: ARDL Bound Test results

F-statistics calculated	**6.1378**	
Critical threshold	BI	BS
5%	2.56	3.49
1%	3.29	4.37

Source : *Authors*

If the calculated F-statistic is higher than the upper critical limit I (1), the null hypothesis will be rejected. If the F statistic is lower than the lower critical value I (0), the null hypothesis cannot be rejected. When this lies between I (0) and I (1), the Co-integration results are considered inconclusive. Variables are then said to be cointegrated if the null hypothesis is rejected, which then means the existence of a long-term relationship between the variables studied. Our results show that the F-statistic is equal to 6.1378, which is compared with the critical values below and above the 5% and 1% significance levels. The test F-statistic is above the upper bound 3.49 and 4.37 respectively. We therefore reject the null hypothesis of no cointegration, and conclude that there is a long-term relationship between the variables in the model. Next, the direction of the relationship between the variables is determined using the Granger causality test (Table 4).

Table 4: Granger causality test

Null Hypothesis:	**Obs**	**F-Statistic**	**Prob.**
PIB does not Granger Cause CO2	27	6.37558	0.0186
CO2 does not Granger Cause PIB		0.12672	0.7250
OC does not Granger Cause PIB	27	1.20770	0.2827
PIB does not Granger Cause OC		17.4325	0.0003
ER does not Granger Cause PIB	27	0.00017	0.0399
PIB does not Granger Cause ER		0.76601	0.3901

Source : *Authors*

Our results show that there is a unidirectional relationship between GDP and CO2 emissions. This implies that an increase in GDP causes an increase in CO2, but that an increase in CO2 does not necessarily cause an increase in GDP. Environmental policies aimed at reducing CO2 emissions will therefore have no negative impact on economic growth. Our results also demonstrated unidirectional causality from GDP to trade openness and from renewable electricity production to GDP. Our equation is then used to determine the long- and short-run coefficients of the ARDL model, taking per capita CO2 emissions (LCO2t) as the dependent variable. The estimated long-run coefficients, which also represent long-run elasticities, are shown in Table 5.

Table 5: ARDL model and estimated variable coefficients (long term)

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
GDP	0.000779	0.000328	2.373134	0.0325
GDP^2	-6,66E-08	7.02E-08	-1.694758	0.1122
OC	0.038066	0.004186	1.926715	0.0446
ER	-0.082442	0.006231	-0.391894	0.0010
C	-0.098258	0.321249	-0.305863	0.7642
R	0.992517			
R^2	0.987172			
Log likelihood	57.77939			
F-statistic	185.6952			
Prob(F-statistic)	0.000000			
Durbin-Watson stat	2.038043			

Source : *Authors*

The coefficient of the GDP variable is equal to 0.000779 and is statistically zero. It implies that a 1% increase in GDP per capita would lead to a 0.000779% increase in CO2 emissions per capita. On the other hand, the sign of the coefficient of the GDP variable^2 IS NEGATIVE, but not significant. This suggests that the Kuznets environmental curve hypothesis is not validated. These results concur with those of Ben Jebli, Ben Youssed (2016) who studied the Tunisian case, those of Zoundi (2017) who carried out their study on a group of African countries, and those of Haq, Zhu et al. (2016) who studied the Moroccan case. Indeed, the Kuznets environmental curve hypothesis is generally confirmed for developed countries (Ben Jebli, Ben Youssed (2016)). The effect of trade openness is positive. Indeed, a 1% increase in this variable would generate a 0.0380% increase in CO2 emissions, which is significant. Finally, the impact of renewable electricity production on CO2 emissions is significant. Indeed, an increase in renewable electricity production would lead to a 0.0824% decrease in CO2 emissions, the dependent variable. Furthermore, the fit parameters R^2 and adjusted R^2 are equal to 0.9925 and 0.9871 respectively, showing that the model is well fitted. The error correction mechanism (ECM) is then used to test the short-term relationship between the variables (Table 6).

Table 6: ECM model estimation (short-term)

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(GDP)	2.07E-05	0.000138	-0.150005	0.0229
D(PIBC)	5.38E-09	2.73E-08	0.196710	0.0469
D(OC)	0.000902	0.001006	0.896386	0.0052
D(ER)	-0.001367	0.003266	-0.418567	0.6819
CointEq(-1)*	-0.559883	0.079196	-7.069603	0.0000

Source : *Authors*

The results show that the coefficient of the error-correction term ecm (-1) is significant, implying that the short-term speed of adjustment to reach equilibrium is significant. Furthermore, this term is equal to around -0.5598, suggesting that when CO2 emissions per capita are above or below their equilibrium value, they would adjust by 55% per year. The coefficients of the lagged variables represent short-term elasticities. These are significant with the expected signs for all variables, however the effect obtained from trade openness and renewable electricity production is zero in the

short term. Diagnostic tests on the residuals of the ARDL regression were also carried out to validate the model (Table 7).

Table 7: Tests on ARDL regression residuals

LM Breusch-Godfrey Serial autocorrelation test
Null hypothesis: No autocorrelation
F-statistics 0. 668735Prob F (10,14) 0.7358
Obs*R-squared 8. 081450Prob Chi-Square (10) 0.6209
ARCH heteroskedasticity test
Null hypothesis: No heteroscedasticity
F-statistics 0. 510537Prob F (1.22) 0.4824
Obs*R-squared 0. 544318Prob Chi-Square (1) 0.4606
Jarque Bera normality test
Null hypothesis: Normality
Jarque-Bera 4.62Prob . 0.099
Ramsey RESET test
Null hypothesis: The model is correctly specified
t-statistics 1.033848Prob . 0.3201
F-statistics 1.068842Prob . 0.3201

Source : *Authors*

The LM autocorrelation test and the correlogram of the regression residuals (Figure 1) confirm the absence of autocorrelation. The ARCH test confirms the absence of heteroscedasticity in the residuals, while the Jarque-Bera test shows that the residuals follow a normal distribution. The Ramsey test shows that there are no missing variables or functional form problems in the model.

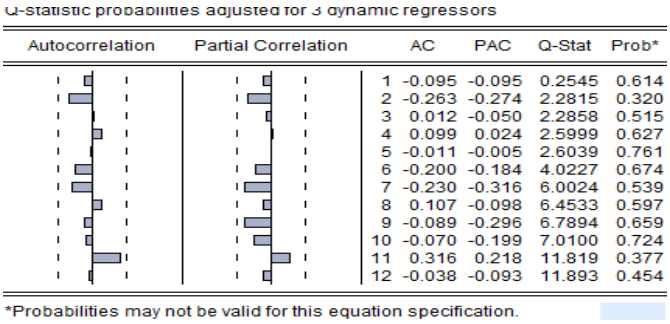

Figure 1: Correlogram of ARDL regression residuals (white noise, no autocorrelation)

Source : Authors

The final step in ARDL or Black Box estimation is to check the stability of the long- and short-term parameters of equation (2). CUSUM based on the cumulative sum of recursive residuals and CUSUMQ based on the cumulative sum of the square of recursive residuals are applied (Figure 2).

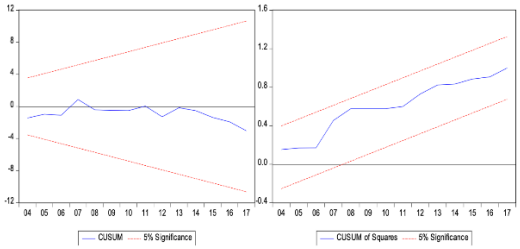

Figure 2: CUSUM and CISUMQ stability tests

Source : Authors

The results show that the plot of CUSUM and CUSUMQ statistics remain within the critical value interval at the 5% threshold, implying that the model coefficients are stable.

4.2. DISCUSSION OF RESULTS

There is growing interest in studying the Environmental Kuznets Curve hypothesis, as it suggests the existence of an economic turning point that will lead to a sustainable development trajectory. Although many studies have focused on the EKC, only a few empirical studies have analyzed the EKC with reference to the Moroccan case, however, none of them have attempted to examine the potential of renewable energy sources within this framework.

The results of our ARDL model demonstrated the existence of a long-term relationship between our variables, namely CO2 emissions, GDP/capita, renewable electricity production and trade openness. The Granger Causality Test then enabled us to determine the direction of this cointegration. Indeed, the test results showed that there is a unidirectional relationship between GDP and CO2 emissions. This implies that an increase in GDP causes an increase in emissions, but that an increase in emissions does not necessarily cause an increase in GDP. Environmental policies aimed at reducing CO2 emissions will therefore have no negative impact on Moroccan economic growth.

Our results also demonstrated a unidirectional causality from renewable electricity production to GDP. The production of renewable electricity would therefore lead to a slight increase in GDP, although the result is not very significant. The beneficial effects of renewable energies on the reduction of CO2 emissions are also observable over the long term. Indeed, an increase in the renewable electricity production variable would lead to a 0.0824% decrease in the dependent variable, CO2 emissions. The favorable impacts of renewable electricity generation on CO2 emissions reduction therefore indicate that environmental sustainability could be achieved by increasing the share of renewables in the electricity generation mix. This is in line with current energy policy, the aim of which is to deploy renewable energies with a view to sustainability and reducing energy dependency.

On the other hand, the sign of the coefficient of the GDP variable^2 is negative, but not significant. This suggests that the Kuznets environmental curve hypothesis is not validated. Our results therefore concur with those of Ben Jebli, Ben Youssed (2016) who studied the Tunisian case, those of Zoundi (2017) who carried out his study on a group of African countries, and those of Haq, Zhu et al. (2016) who also studied the Moroccan case without considering the renewable energy variable. Indeed, the Kuznets environmental curve hypothesis is generally confirmed for developed countries (Ben Jebli, Ben Youssed (2016)). Taking into account the current situation of the Moroccan economy, GDP per capita has not yet reached a level of growth that would allow the curve of CO2 emissions to be inflected. Indeed, according to the Kuznets environmental curve hypothesis, there are three stages in pollution intensity associated with three stages in the growth process. The first stage is considered to be pre-industrial, characterized by low per capita income and increasing pollution. This increase is explained by the use of factors such as polluting technologies in economic activities, lack of awareness and the prioritization of income and profit growth. However, as per capita income and economic growth increase, followed by improvements in social indicators, investment tends to shift towards safer technologies, and households become more willing to direct their spending towards less polluting goods and assets. This marks the turning point in the reduction of environmental pollution.

Our results also showed that economic growth causes trade openness. The impact of trade openness on the environment was also observed. Indeed, a 1% increase in this variable would lead to a statistically significant 0.0380% rise in CO2 emissions. This is inevitably due to the increase in international trade, and therefore an increase in the use of particularly polluting means of transport. In order to reduce the impact of international trade on pollution, it is possible to locate ports close to exporting and importing industrial zones to reduce emissions caused by the transport of goods. In addition, Morocco's proximity to the European Union means it has great potential for green energy exports. Morocco should also benefit from the transfer of renewable energy technology through the import of goods and equipment.

5. CONCLUSION AND SUMMARY :

For some years now, the world has been committed to sustainability, taking into account the various repercussions caused by the development model based particularly on economic growth. Indeed, environmental protection has become a global concern, and has often been seen as an obstacle to economic growth. However, the emergence of new concepts such as "Green Growth" argues that economic growth is not only compatible with environmental protection, but could also generate and be the source of better growth. Green growth relies on investment and innovation to achieve its goals. This obviously involves investment in environmental protection, leading to the creation of so-called "green jobs", and culminating in the creation of green industries, which create added value. A recent theory has provided an essential foundation for the plausibility of green growth. This is the Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesis postulates that the relationship between economic growth and environmental degradation follows an inverted “U” shaped curve. This suggests that economic growth causes environmental deterioration in the initial stage. However, once a certain level of Gross domestic product (GDP) per capital, the increase in environmental degradation is reserved, so that higher GDP per capita leads to environmental restoration, reversing the damage suffered during the early stages of growth. This article examines the theoretical validity of the Kuznets environmental curve in Morocco, incorporating renewable electricity generation and foreign trade as explanatory variables. Committed to sustainable development, Morocco has been deploying renewable energies, particularly solar and wind power, for several years now. This study therefore attempts to test the validity of the Kuznets environmental curve for the Moroccan case, for the period 1971-2010, by considering the role of renewable energies in reducing CO2 emissions. The relationship and direction of causality between the variables were investigated using the ARDL model and Granger causality test. Few empirical studies have investigated the validity of the Kuznets environmental curve in Morocco, and none have examined the potential of renewable energies in this respect. Our results showed that there is a strong cointegration between our variables, and that economic growth can be achieved in parallel with environmental policies aimed at limiting CO2 emissions. Indeed, the Granger Causality Test enabled us to demonstrate that there is a unidirectional relationship between GDP and CO2 emissions. This implies that an increase in GDP would cause an increase in emissions, but that an increase in emissions would not necessarily cause an increase in GDP. Environmental policies aimed at reducing CO2 emissions will therefore have no negative impact on Moroccan economic growth. The role of renewable energies in reducing CO2 emissions has also been demonstrated. Indeed, the results of the study showed that an increase in the variable of renewable electricity production would lead to a 0.0824% reduction in CO2 emissions. Renewable energies would therefore reduce CO2 emissions and contribute to environmental protection. This is in line with current energy policy, which aims to deploy renewable energies to ensure sustainability and reduce Morocco's high energy dependency. However, the hypothesis of the Kuznets environmental curve for the Moroccan case has not been confirmed and our results concur with those of Ben Jebli, Ben Youssed (2016) who studied the Tunisian case, those of Zoundi (2017) who attempted to validate the Kuznets environmental curve for a group of African countries as well as those of Haq, Zhu et al. (2016) who also studied the Moroccan case without taking into consideration the renewable energy variable. Indeed, the results are not surprising, as the Kuznets environmental curve hypothesis is often confirmed for developed countries (Ben Jebli, Ben Youssed (2016)). This result can therefore be explained by the fact that Morocco is still a developing country and that GDP per capita has not yet reached a level of growth that would allow the curve of CO2 emissions to be inflected. The negative impact of trade openness on the environment has also been observed. Indeed, a 1% increase in this variable would lead to a 0.0380% rise in CO2 emissions, which is statistically significant. These results are also in line with those of Ben Jebli and Ben Youssed (2016) and Mahmoud and wang (2019), who explained that this is necessarily due to the increase in international trade, and therefore an increase in the use of means of transport, which are particularly polluting. Indeed, in order to reduce the impact of international trade on pollution, it is recommended that ports be located close to exporting and importing industrial zones in order to reduce emissions caused by freight transport. This article has incorporated the variable of trade openness to form a multidimensional framework. However, following the example of Mahmoud and wang (2019), we refrained from considering social variables, such as the human development index, as our intention was to mainly focused on the validity of the Kuznets environmental curve in Morocco and the role of

renewable energies in reducing CO2 emissions. However, given the importance of human development today, a more in-depth study incorporating this aspect would represent an opportunity to study the Kuznets environmental curve hypothesis in a more varied framework. Indeed, several researchers believe that human capital would influence CO2 emission levels and control energy consumption levels. (Bano et al. (2018) and Salim et al. (2017)).

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APPENDICES

A selection of recent articles on the relationship between CO2 emissions, economic growth and renewable energies within the framework of the Kuznets environmental curve hypothesis.

Authors	**Survey period**	**Territory studied**	**Integrated variables**	**Methodology used**	**Causality ER and CO2**	**CEK assumption**
Ben Jebli, Ben Youssed (2016)	1980-2009	Tunisia	CO2, GDP, GDP^2 ER, ENR, OC	ARDL, VECM Granger	ER → CO2	×
Boluk, Mert (2016)	1961-2010	Turkey	CO2, RE, GDP, GDP^2	ARDL	Not studied	✓
Ben Jebli, Ben Youssed, Ozturk (2016)	1980-2010	25 OECD countries	CO2, GDP, GDP^2 ER, ENR, OC	Test of causality by Granger, FMOLS, DOLS	ER↔CO2	✓
Bilgili, Kocak, Bulut (2016)	1977-2010	17 OECD countries	CO2, RE, GDP, GDP^2	FMOLS, DOLS	ER → CO2	✓
Sugiawan, Managi (2016)	1971-2010	Indonesia	CO2, RE, GDP, GDP^2	ARDL	Not studied	✓
Zoundi (2017)	1980-2012	25 afric an countries	CO2, RE, GDP, GDP^2	FMOLS, DOLS	ER → CO2	×
Dong et al (2018)	1993-2016	China	CO2, GDP, GDP2, ER, EN	ARDL, Granger, FMOLS, DOLS	ER↔CO2	✓