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Analysis of the Kuznet Hypotheses on the relationship between CO2 emissions and GDP growth in Morocco

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Abstract: In the current context of climate change, the issue of reconciling economic growth and environmental preservation has become a major concern, especially for developing countries. This study focuses on carbon dioxide (CO2) emissions and examines how economic growth affects the environment by testing the validity of the Kuznets environmental curve for Morocco. For this purpose, the ARDL (Auto Regressive Distributed Lag) method, also known as "black box", is used.

The first part of this paper presents a review of the literature on the different studies that have examined the validity of the environmental Kuznets curve, as well as a brief overview of the energy demand in Morocco. It also looks at the evolution of CO2 emissions by sector and fuel type, as well as the energy strategy adopted by the country. In the second part, using econometric tools, the study examines the long-term relationship between CO2 emissions and real Gross Domestic Product (GDP), introducing other explanatory variables such as energy consumption and international trade, for the period 1990-2021.

The results of the econometric analysis confirm the existence of a positive long-run relationship between CO2 emissions and real GDP, and show that the direction of this relationship is from CO2 emissions to GDP, according to Granger causality tests. Furthermore, the ARDL regression results validate the Kuznets environmental curve hypothesis for Morocco.

Keywords: Economic growth, Environment, Kuznets curve, ARDL.

Résumé : Dans le contexte actuel de changement climatique, la question de la conciliation entre croissance économique et préservation de l'environnement est devenue une préoccupation majeure, notamment pour les pays en développement. Cette étude se concentre sur les émissions de dioxyde de carbone (CO2) et examine comment la croissance économique influe sur l'environnement, en testant la validité de la courbe environnementale de Kuznets pour le Maroc. Pour cela, la méthode ARDL (Auto Regressive Distributed Lag), également appelée "black box", est utilisée. La première partie de cet article présente une revue de la littérature sur les différentes études qui ont examiné la validité de la courbe environnementale de Kuznets, ainsi qu'un bref état des lieux de la demande énergétique au Maroc. Elle se penche également sur l'évolution des émissions de CO2 par secteur et type de carburant, ainsi que sur la stratégie énergétique adoptée par le pays. Dans la seconde partie, à l'aide d'outils économétriques, l'étude examine la relation de long terme entre les émissions de CO2 et le Produit Intérieur Brut (PIB) réel, en introduisant d'autres variables explicatives telles que la consommation d'énergie et le commerce international, pour la période 1990-2021. Les résultats de l'analyse économétrique confirment l'existence d'une relation de long terme positive entre les émissions de CO2 et le PIB réel, et montrent que le sens de cette relation va des émissions de CO2 vers le PIB, d'après les tests de causalité de Granger. En outre, les résultats de la régression ARDL valident l'hypothèse de la courbe environnementale de Kuznets pour le Maroc.

Mots-clés : Croissance économique, Environnement, courbe de Kuznets, ARDL.

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1. Introduction

Climate change is one of the major challenges facing humanity today. Nevertheless, during the last decades, the climate changes seem to have intensified, which intensified, which has led the public to question the causes of these changes and the consequences they may and the short- and long-term consequences they may have on lifestyles, health, the ecosystem and the economy.

Since the seventies, the notion of development based on continuous economic growth has been the subject of various criticisms, calling into question its physical sustainability. The report "The Limits to Growth"[1] published in 1972 by the Meadows team contributed to popularize this pessimistic vision of economic growth by calling for a halt to growth. At the first United Nations conference on the human environment in June 1972, Maurice Strong and Ignacy Sachs proposed the concept of ecodevelopment, which aimed to address the concerns of developing countries while adopting a prudent ecological approach. However, this concept was later replaced by the notion of sustainable development, proposed by the World Commission on Environment and Development (WCED) in 1983. The WCED report, entitled "Our Common Future"[2] and published in 1987, defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This report recognizes the negative effects of economic growth on the environment, while emphasizing the importance of trade liberalization and industrialization in reducing social inequalities and fighting poverty. Since then, many controversies have emerged about the effects of accelerated economic development on the state and quality of the environment.

In recent years, access to environmental data has made it possible to test and estimate the relationship between improvements in per capita income and environmental quality, as well as to determine the extent to which pollution is independent of economic growth. The first research in this area dates back to Grossman and Krueger (1991)[3], who showed that after an initial phase of environmental degradation, it reverses above a certain level of income, forming an "inverted U" shaped relationship also known as the "environmental Kuznets curve"[4], referring to the Kuznets curve on social inequality and economic development.

This curve is politically important because it encourages developing countries to catch up by showing that economic growth can help improve environmental quality. Thus, this optimistic approach suggests that the solution to environmental problems is to increase wealth, which implies that economic growth and environmental preservation are not incompatible, but rather complementary to achieve sustainable development in accordance with the recommendations of the Bruntland Commission.

The curve presented here feeds into the economic debate on green growth, because it is crucial from a political point of view. It encourages developing countries to catch up. This optimistic

[1] Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1972). The limits to growth. New York, 102, 27.

[2] Brundtland, G. H. (1987). Report of the World Commission on environment and development:" our common future. » United Nations.

[3] Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American free trade agreement (No. w3914). National Bureau of Economic Research

[4] Figure 1

view of the relationship between environmental and economic aspects suggests that growth can remedy its own ills. Thus, the best way to solve environmental problems is to become rich, which implies that the environment and growth are not mutually exclusive. On the contrary, they can coexist for sustainable development, in line with the recommendations of the Bruntland Commission, which advocates the necessary reduction of poverty to improve the quality of the environment.

We seek to enrich existing discussions of the relationship between economic growth and the environment by specifically investigating the presence of a turning point in CO2 emissions in Morocco, as well as the level of per capita income corresponding to this point, if it exists.

According to the study conducted by Berahab Rim (2017)[5] in Morocco, the results of the econometric analysis show a positive long-term correlation between CO2 emissions and real GDP. Granger causality tests suggest that this relationship runs from economic growth to CO2 emissions. Furthermore, the ARDL regression results support CEK's hypothesis that economic growth initially leads to an increase in CO2 emissions, but reaches an inflection point where these emissions decline.

To do so, this paper follows the methodology of recent studies on the nexus "economic growth-environmental pollution" nexus (Ang, 2007[6]; Soytas et al, 2007; Ang, 2008[7]) by also integrating energy consumption and foreign trade as explanatory variables. to test the validity of the Kuznets hypothesis in the Moroccan context and to estimate the GDP per capita necessary to reach this turning point.

2. Review of the literature :

Our literature review will start with a sequence of the different works that have verified the Kuznet curve. We will start with Grossman and Krueger pioneered the observation of an empirical relationship between environmental indicators and the concentration of pollutants in their pioneering work in 1991 on the impact of NAFTA in the United States. They proposed to transpose the relationship already observed by Simon Kuznets in 1955 between social inequalities and the environmental paradigm.

They studied the impact of per capita income on sulfur dioxide emissions and airborne particles. In their subsequent work in 1995[8], the two authors extended their study to other countries while taking into account four variables as indicators of environmental quality, namely urban air quality pollution, oxygen levels in water, fecal contamination and heavy metal contamination for the analysis of river conditions. Regressions in both studies led Grossman and Krueger to conclude that economic growth does not necessarily lead to a deterioration in environmental quality, as the environment improves at a certain income level.

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[5] Berahab,Rim.(2017). « Emissions de Dioxyde de Carbone et Croissance Economique au Maroc : Une Analyse de la Courbe Environnementale de Kuznets ». Revue d'OCP Policy Center ; Publied on March 2017.

[6] Ang J., (2007). "CO2 emissions, energy consumption and output in France". Energy Policy 35, 4772 – 4778.

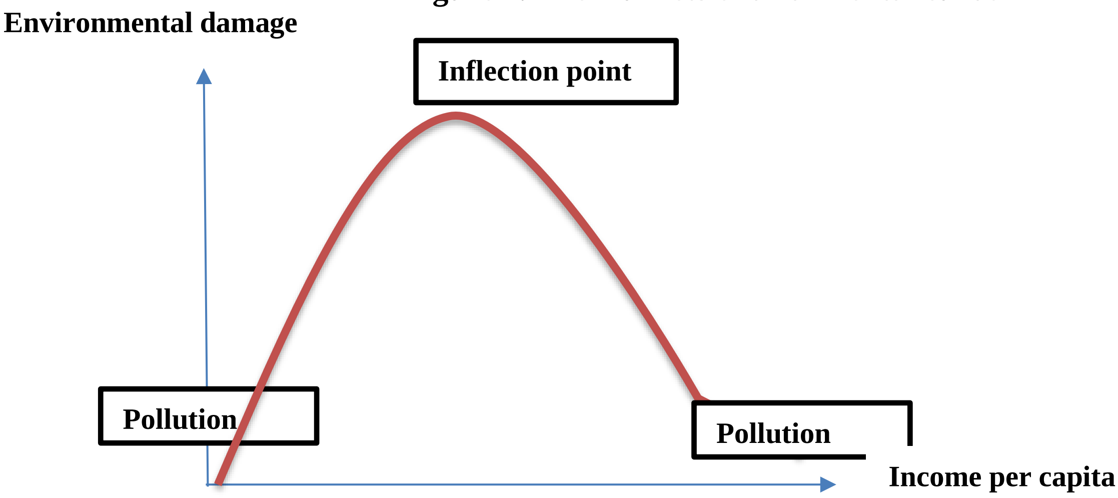
[7] Ang J., (2008). "Economic development, pollutant emissions and energy consumption in Malaysia". Journal of Policy Modeling, 30, 271 – 278.

[8] Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. The quarterly journal of economics, 110(2), 353-377.

The authors observed an inverted U-shaped curve similar to that established by Kuznets, with turning points located at income levels between $5000 for air pollution and $8000 for water pollution.

Much work has followed to test the validity of this curve, and similar results have been found primarily for local pollutants, such as Shafik and Bandhyopadhyay (1992)[9] and Selden and Song (1994)[10].

Figure 1. The Kuznets environmental curve



The popularization of the Kuznets curve is attributed to the study by Shafik and Bandyopadhyay (1992), which examined 10 environmental indicators and was used as the basis for the World Bank's 1992 report on environment and development. The term "Kuznets environmental curve" originated in the work of Panayotou (1993)[11] for the International Labour Organization. The conclusions of these two studies support the existence of an inverted U-shaped relationship between certain pollution indicators and per capita income.

The relationship between economic growth and the environment is subject to much controversy, both in terms of the form and the econometric specification to be used. Although most studies of the Kuznets curve use a linear, semi-logarithmic or log-linear polynomial specification, other functions are sometimes used to support or refute the existence of the curve. Nonparametric approaches have also been used to avoid specifying a priori the functional form of the relationship between environmental indicators and income.

For example, in a study of percentages of land protected and in an analysis of CO2 emissions for 100 countries, nonparametric approaches led to different conclusions than those obtained with parametric specifications. Other research has also explored alternative functional forms, such as Gamma and Weibull functions, which have allowed for easier interpretation of

[9] Shafik, N., & Bandyopadhyay, S. (1992). Economic growth and environmental quality: time-series and cross-country evidence (Vol. 904). World Bank Publications.

[10] Selden, T. M., & Song, D. (1994). Environmental quality and development: is there a Kuznets curve for air pollution emissions?. Journal of Environmental Economics and management, 27(2), 147-162.

[11] Panayotou, T. (1993). Empirical tests and policy analysis of environmental degradation at different stages of economic development (No. 992927783402676). International Labour Organization.

parameters and analytical determination of the turning points of the environmental Kuznets curve.

Soytas et al (2007)[12] studied the causal relationship between income, energy consumption and CO2 emissions for the case of the United States for the period 1960-2004. They proved the validity of the the Kuznet environmental curve hypothesis and established the existence of a unidirectional Granger causal relationship that goes in the direction of energy consumption to CO2 emissions.

In summary, since the 1990s, studies have detected an inverted U-shaped relationship between economic growth and certain pollution indicators. However, the Kuznets curve has been questioned for various theoretical, methodological and empirical reasons. Moreover, there are different forms of the income-environment relationship and several possible explanations and interpretations. Although the Kuznets hypothesis remains interesting for developing countries that have to deal with other concerns such as unemployment and poverty, it is not an absolute reality.

In our view, the Kuznets environmental curve is plausible because households must reach a certain level of well-being before they take the environmental issue into account. However, it is difficult to rely solely on individual consciences or government policies to reduce pollution, especially for a global problem requiring the collaboration of several countries. Economic competition, lack of immediate and direct effect, and the emergence of new types of expenditures can be obstacles to achieving any environmental goal.

Therefore, for economic growth to reduce the environmental price, advanced technical progress is needed to improve the efficiency of the means of production, diversify the sources of energy and raw materials, and implement less polluting production processes with reasonable costs.

Despite the costs of research and development, they remain negligible compared to the price that preserving the environment would currently cost a price that could slow down economic growth and threaten human existence on earth. In other words, economic growth will provide more funding for scientific research, eventually transforming our economy into a sustainable development economy. In addition, people will be more attentive to environmental issues as their incomes increase.

3. Morocco's energy situation and trends

3.1. State of the situation

Morocco relies heavily on imported fossil fuels in its energy sector. In 2019, these energies accounted for 90.6% of the country's primary energy consumption, with oil as the largest source (56.7%), followed by coal (30%) and gas (3.9%). Renewable energies, such as biomass (5.9%), wind and solar (3.4%), contribute only 9.7%. As far as energy production in Morocco is concerned, it will only meet 10.1% of the country's needs in 2019[13].

This production is mainly made up of renewable energies (96.5%), such as biomass and waste (58.4%), wind and solar (33.2%), and hydroelectricity (4.8%). In terms of electricity, 17.2% of

[12] Soytas U., Sari R., Ewing T., (2007). "Energy consumption, income and carbon emissions in the United States." Ecological Economics, vol. 62, issue 3-4, pages 482-489.

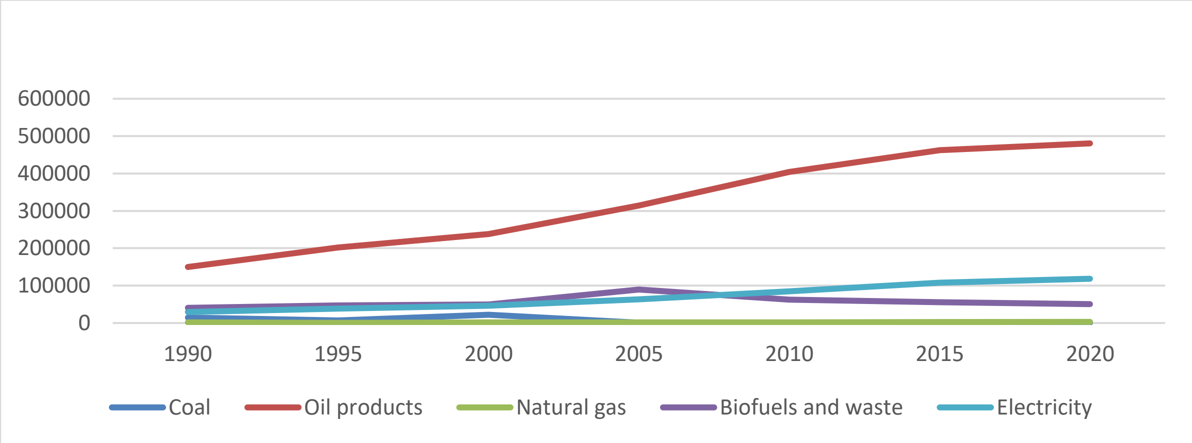
[13] Source: international agency of energy (IAE)

the energy consumed in Morocco comes from this source. However, 81% of this electricity is generated from fossil fuels (coal 67.6%, gas 11.8%, oil 1.5%), while renewable energies account for only 18.8% (hydro 3.2%, wind 11.6%, solar 4%), although their share has increased considerably in recent years.

For example, the share of wind power has increased from 2.8% in 2010 to 11.6% in 2019, thanks to state support that aims to increase their share of installed capacity to 52% in 2030[14].

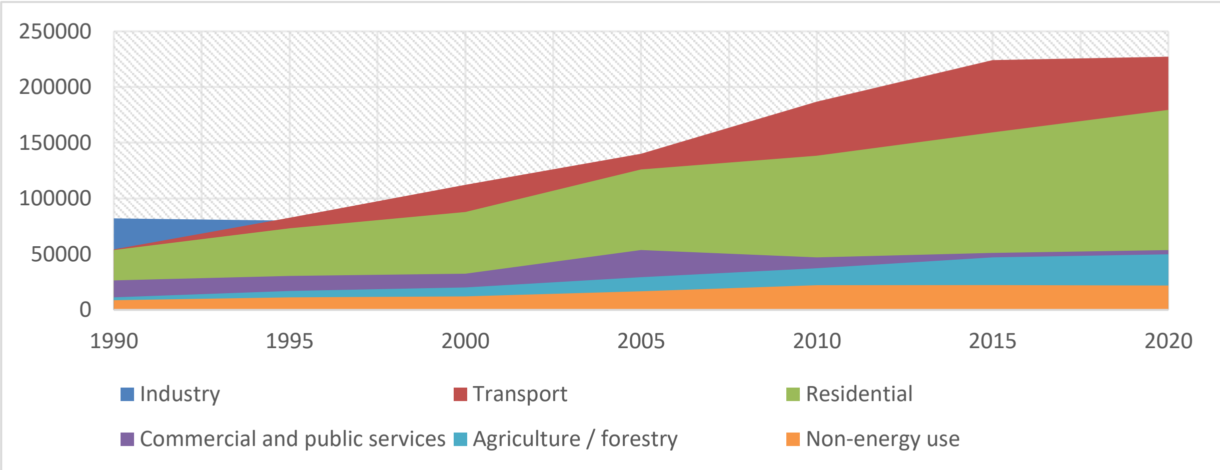
However, the two graphs below show the evolution of energy consumption in Morocco from 1990 to 2020, and reveal that the consumption of petroleum products has increased steadily over the years, particularly in the transport and residential sectors.

Figure 2. Final consumption by source, Morocco 1990-2020



Source: Author, Data IAE

Figure 3. Final consumption by sector, Morocco 1990-2020



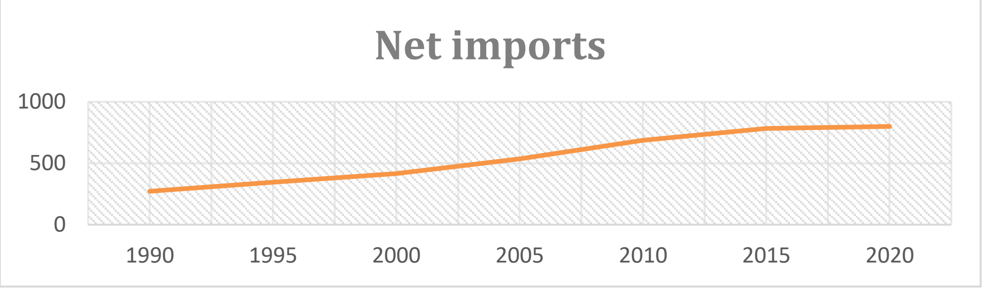
Source: Author, Data IAE

We note from Figure 4, a decline in value, energy imports are mainly due to the fall in oil prices from 2015. In addition, these imports now represent a little less than 30% of exports and their

[14] Source: Ministry of Energy, Mines, Water and Environment (MEMEE)

evolution plays a major role in the behavior of the country's trade balance. The share of the oil products bill is preponderant reaching 75% of the total energy bill.
According to Amegroud Tayeb (2022)[15] considered that the coming years will be marked by a transition from an energy mix dominated by fossil fuels to a scenario where renewable energies would play a more important role represents the challenge of the coming years for Morocco. Given the size of the needs, the socio-economic infrastructures at stake, the transformation of the transformation of the energy system will be complex, sometimes costly, and will require strong and clear which will have a positive impact on the reduction of energy imports.

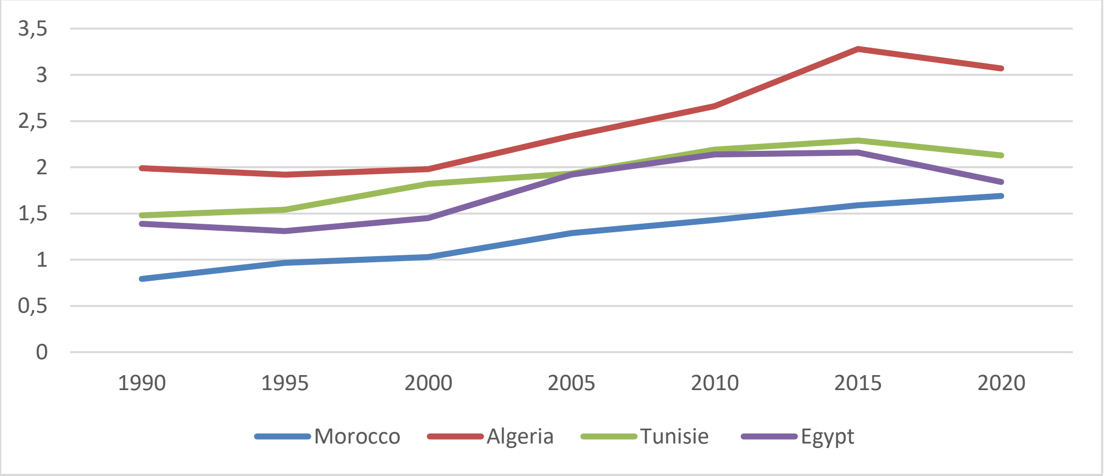
Figure 4. Evolution of energy products imports between 1990 and 2020



Source: Author, Data (IAE)

According to the historical analysis of CO2 emissions in Morocco, there is a continuous increase in these emissions between 1990 and 2020, although this growth does not exceed 1.5 times the initial level. However, the graph shows that CO2 emissions per capita are relatively low in Morocco compared to its neighboring countries. In other words, Morocco is a low emitter of CO2 per capita.

Figure 5. CO2 emissions per capita in the Maghreb



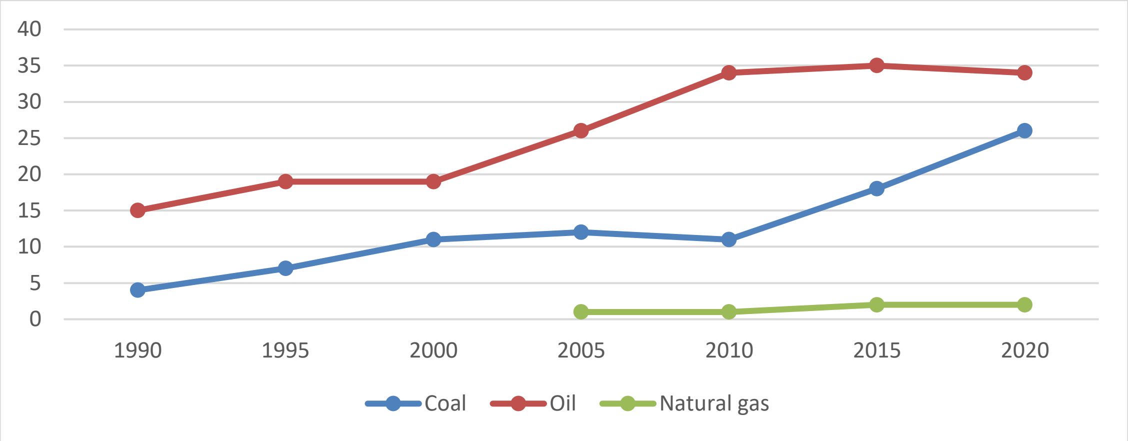
Source: Author, Data (IAE)

Figure 6 shows that oil consumption remains the main source of CO2 emissions, accounting for 56% of total emissions in 2020, followed by coal (41%) and natural gas (3.7%).
However, CO2 emissions due to oil experienced a sharp increase between the years 2000 and 2011, before stabilizing between 2012 and 2020, thanks to the efforts of public authorities to

[15] Amegroud, Tayeb.2022 « Quelques sources d'énergie utilisées au Maroc et pour quels usages ». Fondation Heinrich Böll Rabat.

reduce CO2 emissions through the implementation of the recommendations and objectives of the COP 22.

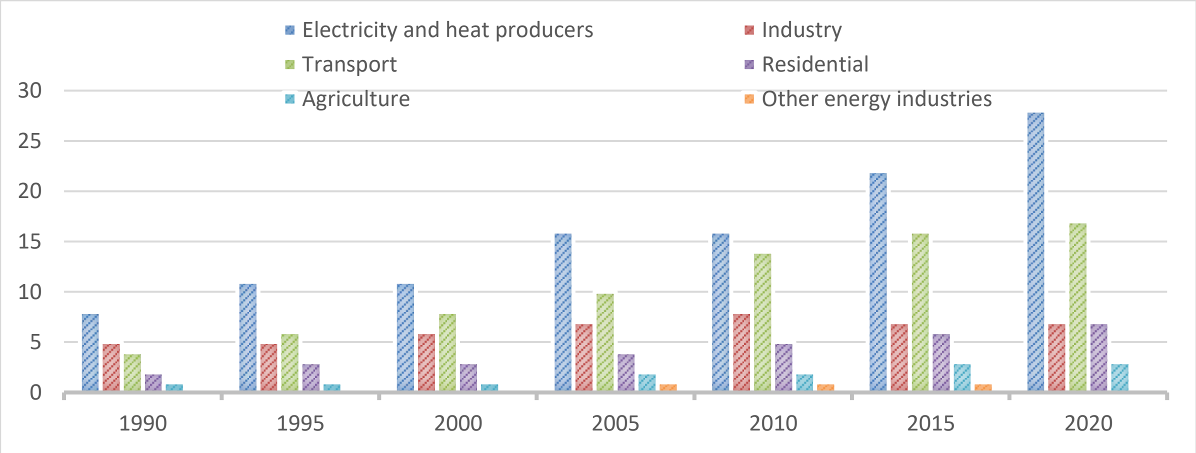
Figure 6. CO2 emissions by fuel in Morocco, 1990-2020 in MtCO2



Source: Author, Data (IAE)

According to Figure 7, the power generation and transportation sectors are the largest emitters of CO2, accounting for nearly 72.2% of total CO2 emissions per capita in 2020. The manufacturing, buildings and public works sectors follow this.

Figure 7. C02 emissions per capita by sector in percent, Morocco between 1990 - 2020



Source: Author, Data (IAE)

3.2.Energy Strategy of Morocco

Morocco's new energy strategy has been hailed internationally on many occasions. In this sense, the Energy Efficiency Visionary Award was given to His Majesty King Mohammed IV in May 2017, reinforcing Morocco's efforts in terms of sustainable energy development. Morocco also won the "Best State Strategy" award for renewable energy at the Africa Investments Forum, held in November 2017 in Paris.

Through measures such as the ban on importing old cars, improved thermal regulations for new buildings, and the "Green Mosque" program, Morocco has successfully adopted more efficient products and equipment in mosques and public buildings.

However, these measures are not enough to meet energy and climate goals. Transforming AMEE into a full-fledged energy efficiency agency, with programs and financial resources, would be a radical change and is necessary. Currently, the government in consultation with several key ministries and AMEE is developing a new energy efficiency program, which is an opportunity. The government should move quickly to implement the actions planned for 2020 and present the National Energy Efficiency Strategy 2030.

Morocco's post-CP21 climate change commitments continue to be implemented through the 2009 strategy, which remains central, as well as the strategic directions of Morocco's energy policy.

To effectively implement energy and climate policies and measures, it is important to prioritize actions and focus on the most important tasks. In this context, sound cost-benefit analysis is essential to provide the government with the best possible information on energy and climate issues, allowing for informed decisions based on cost effectiveness.

Legislative measures have been put in place to support the implementation of elements of the 2009 strategy, including the creation of an independent electricity market regulator in 2016, whose director was appointed in 2018, as well as plans to further open the market. Morocco has also made significant progress in deploying large-scale wind and solar programs, as well as research and development infrastructure for energy technologies.

Morocco has begun its energy transition by transforming the electricity sector through an ambitious renewable energy program that has created strong momentum to support the transformation of the entire energy system and economy. Sectoral coupling offers additional opportunities for renewable energy use in other sectors such as heating and cooling, transportation, and water management. However, Morocco needs to develop a more integrated vision for its energy sector and encourage the active engagement of consumers in the transition process.

4. Econometric specifications and estimation methodology

4.1.Methodology:

The methodology used in this paper is based on recent studies on the link between economic growth and environmental pollution (Ang, 2007; Soytas et al, 2007; Ang, 2008 and Berahab Rim 2017) .In addition; we included energy consumption and foreign trade as explanatory variables. In order to test the long-run relationship between CO2 emissions, economic growth, energy consumption, and foreign trade, and to assess the validity of the CEK hypothesis, we proposed the following linear logarithmic form:

$$LCO2_2 = \beta_0 + \beta_1 LCE_t + \beta_2 LPIBP_t + \beta_3 LPIBP^2{}_t + \beta_4 LOC_t + \varepsilon_t$$

Which are;

LCO2: Emissions per capita; LCE: Energy consumption per capita; LPIB: The Real GDP per capita; $LPIBP^2$: Real GDP per capita squared;

LOC: The trade openness ratio which is used as a proxy for trade & ε: the error term.

$\beta_{1.2.3.4}$: The parameters represent the long term elasticity of CO2 emissions with respect to LCE, LPIBP, $LPIBP^2$ and LOC respectively.

Since our data are time series, it is essential to estimate our model and detect causality between the different variables. This implies checking the stationarity of the data, which will allow us to determine the order of integration of the variables and to decide whether we will use a VAR or a cointegration approach by application ARDL method. The data used in this study are extracted from the World Bank and International Energy Agency (IEA) World Development Indicators database of the World Bank and the International Energy Agency (IEA) during the period 1990 to 2021.

Cointegration is a concept that assumes that there is a long-run equilibrium relationship between certain economic variables. Although these variables may deviate from this relationship in the short run, economic forces are expected to bring them back into equilibrium. The most common cointegration tests have been proposed by Engle and Granger (1987)[16], Stock & Watson (1988) and Johansen (1988)[17].

For this study, we chose a different method called ARDL (Autoregressive Distributed Lag Model), also known as the black box model. This method was introduced by Pesaran and Shin (1999)[18] and developed by Pesaran, Shin and Smith (2001)[19]. This method is more appropriate for small sample sizes, as is the case for this study. In addition, it can be applied to non-stationary time series without the constraint of the same order of integration, which distinguishes it from other tests. Moreover, this method does not pose an endogeneity problem.

The ARDL approach involves several steps, the first of which is to transform equation (1) in an appropriate way:

$$\Delta LCO2_2 = \beta_0 + \sum_{i=1}^{p} \delta_i \, \Delta LCO2_{t-1} + \sum_{i=1}^{p} \alpha i \, \Delta LCE_{t-1} + \sum_{i=1}^{p} \omega_i \, \Delta LPIBP_{t-1} + \sum_{i=1}^{p} \gamma_i \, \Delta LPIBP^2{}_{t-1} + \sum_{i=1}^{p} \theta_i \, \Delta LOC_{t-1} + \mu ECM_{t-1} + U_t$$

4.2. Results:

Applying the ARDL methodology for cointegration analysis requires the following steps:

1. Test the stationary of the time series;
2. Select the optimal number of lags;
3. Perform the "Bound Test" to establish the long-term relationship;
4. Estimate the long run and short-run coefficients;
5. Test the stability of the model through residual analysis and the CUSUM and CUSUMSQ technique (Brown et al, 1975).

To determine the order of integration of the time series, this study uses the Augmented Dickey Fuller (ADF) and Phillips Perron (PP) stationary tests. This step is important in order to use the Bound Test, which requires that the series not be integrated of order 2, because the critical values needed are only for integration levels zero and 1, as shown in the results presented in

[16] Engle R., Granger C., (1987). “Co-integration and Error Correction: Representation, Estimation, and Testing”. Econometrica, Vol. 55, issue 2, pages 251-76.

[17] Johansen S., (1988). “Statistical analysis of co-integration vectors”. Journal of Economic Dynamics and Control, Vol. 12, issue 2-3, pages 231-25

[18] Pesaran M. H., Shin Y., (1999). “An autoregressive distributed lag modelling approach to cointegration analysis”. Cambridge University Press, Cambridge Chapter II.

[19] Pesaran M.H., Smith R.P., (1998). “Structural analysis of co-integrating VARs”. Journal of Economic Survey.

Table 1. These tests indicate that all series are non-stationary in level but stationary in first difference, which means that they are integrated of order 1.
Next, the AIC, SC, LR, and HQ criteria are used to select the optimal number of lags of the vector auto-regression (VAR) (Table 2). Four VAR models (P = 0, 1, 2, 3) were estimated for the period 1971-2014. The AIC criterion suggests a lag of 3, while the LR, SC, and HQ criteria suggest a lag of 1. The latter criterion is chosen for this study.
The first step is to test the stationary of the data using the Dickey-Fuller test, to determine the order of integration.

Table2. Statistics and choice criteria for the selection of the optimal model delay

Lag	LogL	LR	AIC	SC	HQ
0	284,53	-	-19,27	-19,04	-19,2
1	385,22	159,7	-24,49	**-23,08***	-24,05
2	423,91	**48,031***	-25,44	-22,85	**-24,63***
3	452,96	26,0399	**-25,72***	-21,94	-24,54

Source: Author

Notes : *indique le retard sélectionné par le critère choisi.
LR: Sequential modified LR test statistic.
AIC: Akaike information criterion.
SC: Schwarz information criterion.
HQ: Hannan-Quinn information criterion

Once the order of integration of the variables and the optimal lag of the model have been determined, the ARDL (also known as Black Box) approach is used to evaluate the cointegration and determine the long-run relationship between the variables. The Bound Test is used for this, and calculates an F-statistic (as shown in Table 3). This F-statistic tests the null hypothesis that the coefficients of the lagged variables in equation (1) are zero. The F-statistic is equal to 16.38, which is compared to the critical values below and above the significance level of 5% and 1%. The test statistic is above the upper bound (4.01 and 5.06 respectively). Therefore, the null hypothesis of no cointegration is rejected and we conclude that the existence of a long-run relationship between the variables in the model

Table 3. Result ARDL & Bound Test

F-Statistique		**16,38**
Signification Seuil	**I(0) Bound**	**I(1) Bound**
5%	**2,86**	**4,01**
1%	**3,74**	**5,06**

Source: Author

The Granger causality test is used to determine the direction of the relationship between the variables under study (primarily GDP per capita and CO2 emissions). The results of the test, presented in Table 4, indicate that CO2 emission has an influence on economic growth (LPIBPt, $LPIBt^2$), not the other way around. This conclusion is also valid for another variable analyzed. Thus, it can be concluded that the adoption of an environmental policy is unlikely to have a negative impact on economic growth.

Table 4. The Granger Causality Test

Hypothèse nulle	F-Statistique	Prob
LCO2t does not granger Cause LPIBPt	6,42	0,056*
LPIBPt does not granger Cause LCO2t	0,07	0,91
$LPIBPt^2$ does not granger Cause LCO2t	0,25	0,34
LCO2t does not granger Cause $LPIBPt^2$	9,64	0,008*

Source: Author

Equation (2) is used to estimate the short- and long-run coefficients of the ARDL model, with CO2 emissions per capita (LCO2 t) as the dependent variable. The long-term elasticity's are represented by the estimated long-term coefficients, which are displayed in Table 5. The coefficient on the LCE 2 variable is equal to 0.4 and is statistically significant, indicating that a 1% increase in per capita energy consumption would result in a 0.4% increase in per capita CO2 emissions. This result is consistent with the work of Liu (2005) and Ang (2007, 2008, and 2009) who also found a positive relationship between energy consumption and CO2 emissions. Similarly, the long-run elasticity of CO2 emissions per capita with respect to GDP per capita (LPIBP t) is equal to 0.26 and is statistically significant, meaning that a 1% increase in real GDP per capita squared would result in a 0.26% increase in CO2 emissions per capita. The negative coefficient on the LPIBP t variable, which is statistically insignificant, supports the hypothesis of declining CO2 emissions when the country reaches high-income levels. This result supports the CEK hypothesis that CO2 emissions initially increase with income, reach a plateau and then decline.

Table 5. ARDL model and estimated coefficients of variables (long term)

Dependant Variable LCO2t				
V.EXP	Coef	Stand-Error	T-Statistic	Prob
LCEt	0,4	0,065	6,1486	0
LPIBt	-0,059	0,061	-0,9634	0,34
$LPIBt^2$	0,26	0,079	3,3183	0,0026
LOCt	12,23	6,57	1,8621	0,07
C	-3,79	0,3448	-11,018	0
R^2	0,987	R^2Adjusted		0,986
F-Stat	548,32	DW Stat		1,62

Source : Author

Note: ARDL (4, 4, 4, 4, 3) selected by Criteria SC.

Although the sign of the coefficient of the LOC t variable is negative, it is not significant. Its coefficient is 12.23, indicating that the contribution of foreign trade to CO2 emissions is significant. On the other hand, the fit parameters R^2 and adjusted R^2 are both equal to 0.987 and 0.986, respectively, indicating that the model is well fitted.

The error correction mechanism (ECM) is used to test the short-term relationship between the variables (Table 6). The results show that the coefficient of the error correction term ecm (-1) is significant, implying that the speed of short-term adjustment to reach equilibrium is significant. This term is about -0.89, suggesting that when CO2 emissions per capita are above or below their equilibrium value, they would adjust at a rate of 89% per year. The coefficients on the lagged variables represent short-term elasticity's, which are significant with the expected signs for all variables. For example, a 1% increase in per capita energy consumption would lead to a 31% increase in per capita CO2 emissions in the short run.

Table 6. Estimation of the ECM model (short term)

Dependant Variable LCO2t				
V.EXP	Coef	Stand-Error	T-Statistic	Prob
LCEt	0,31	0,042	7,52	0,0017
LPIBt	-0,24	0,034	-7,64	0,0015
$LPIBt^2$	1,085	0,06	16,8	0,001
LOCt	4,446	3,0238	14,7	0,001
ECM (-1)	-0,89	0,13	-15,38	0,0001
R^2	0,987	R^2Adjusted	0,961	

To confirm the validity of the ARDL regression model, diagnostic tests were performed on the residuals (Table 7). The LM test for autocorrelation and the correlogram of the residuals confirmed the absence of autocorrelation. The White test also confirmed the absence of heteroscedasticity of the residuals, while the Jarque-Bera test showed that they follow a normal distribution. Furthermore, the Ramsey test showed that there are no missing variables or functional form problems in the model

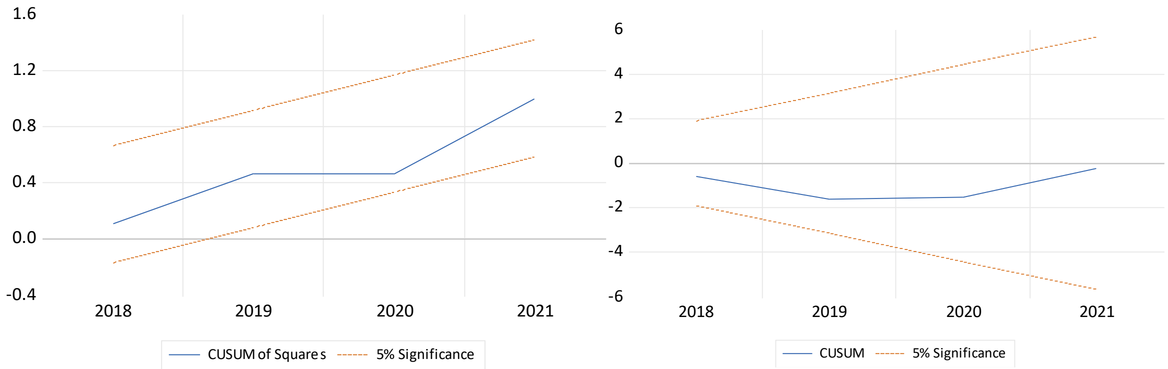
Table 7. Tests on the residuals of the ARDL regression

Breusch-Godfrey Test			
Null Hypothesis: No Seriel correlation			
F-Statistic	1,144	Prob	0,58
Obs R-Squared	2,168	Prob	0,52
Heteroskedasticity Test			
Null Hypothesis: Homoskedasticity			
F-Stat	1,66	Prob F(23,4)	0,33
Obs R-Squared	25,35	Prob Chi-Square(23)	0,33
Scaled Explained $$	0,43	Prob Chi-Square(23)	1
Jacque Berra Test			
Jacque Berra	0,13	Prob	0,93
RESET Ramsey Test			
Null Hypothesis: Model is correctly specified			
T-Statistic	0,41	Prob	0,7
F-Statistic	0,16	Prob	0,7

The last step of the ARDL or Black Box estimation is to check the stability of the long and

short-term parameters of equation (2). The CUSUM technique based on the cumulative sum of the recursive residuals and CUSUMQ based on the cumulative sum of the square of the recursive residuals are applied (figure 8).
The results show that the plot of the CUSUM and CUSUMQ statistics remain within the range of critical values at the interval of critical values at the 5% threshold, which implies that the coefficients of the model are stable.

Figure 8. Stability Test CUSUM & CUSUMQ



5. Conclusion :

Morocco has adopted an energy transition strategy that aims to balance environmental, economic, and social dimensions by improving the living environment of citizens, strengthening the sustainable management of natural resources, and developing renewable energy. This conclusion is consistent with the objectives of reducing greenhouse gas emissions, including carbon dioxide (CO2), set by this strategy by 2030.
The main objective of this study is to analyze the impact of economic growth on the environment, by examining the validity of the Kuznets environmental curve (KEC) for Morocco over the period 1990-2021, using CO2 emissions per capita as an environmental indicator. The ARDL (black box) methodology was used to test the CEK hypothesis, and the results show a strong long-term relationship between CO2 emissions per capita and income per capita, thus confirming the existence of the CEK for the case of Morocco. Moreover, the Granger causality test indicates a unidirectional causality from CO2 emissions to per capita income, implying that an environmentally friendly energy policy can be implemented without risking harm to economic growth.
CUSUM and CUSUMQ techniques were also used to show that the coefficients of the cointegrated ECM model are stable. Furthermore, energy consumption is a significant determinant of CO2 emissions, while the international trade ratio, although its coefficient is positive, is also a significant determinant. This reflects the economic reality of Morocco, where all energy products are sourced externally due to its degree of economic openness.

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