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EMPIRICAL ANALYSIS OF THE ENVIRONMENTAL KUZNETS CURVE FOR ECONOMIC GROWTH AND CO_2 EMISSIONS IN NORTH AFRICAN COUNTRIES

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Abstract: This study aimed at examining the relation between economic growth and carbon dioxide (CO_2) emissions in North African countries in the period 2000-2018. To prove this, the author applied the OLS method of the two variables describing the Environmental Kuznets Curve: GDP per capita and CO_2. The results show that GDP per capita reflects the influence of changes in the level of income on environmental pollution in five of the seven countries surveyed.

Keywords: CO_2 emissions, economic growth, environment, panel cointegration approach.

1. Introduction

Environmental issues are the subject of much scientific research and are of constant concern to governments at the highest level around the world (Alkhathlan and Javid, 2013; Wang, Zhou, and Wang, 2011). In fact, the destruction of the ozone layer by the release into the atmosphere of greenhouse gases, including carbon dioxide (CO_2), constitutes the main threat to humanity. According to Stern (2007), it could cost the entire world's economy up to $550 billion if real action is not taken. Due to the increasing use of energy, carbon dioxide emissions have increased dramatically over the past century, with a direct link to economic growth and development (Lau, Tan, Lee, and Mohamed, 2009; Soytas et al., 2009; Soytas, Sari, and Ewing, 2007). The relation between CO_2 emissions, economic growth and energy consumption is therefore at the heart of current economic issues.

The link between economic growth and the environment is a controversial issue. Traditional economic theory proposes a trade-off between economic growth and environmental quality (Lee, Chung, and Koo, 2005), where a destructive or mutually helpful relation can coexist. The first case leads to the hegemony of economic interests, causing the continuous destruction of the environment. At this point, countries superimpose the conditions required by the market in favour of increased production – although, according to Lee et al. (2005), greater growth in the scale of production causes greater pollution – and consumption, without adjusting the controls to the exploitation of raw materials and the emission of pollutants, thus putting stress on the environment in all economic systems at the global level (Munda, Nijkamp, and Rietveld, 1994). In the early stages of economic growth, degradation and pollution increase, although several empirical cases show that this trend can be reversed when the status of a developed country is achieved, thus benefiting the environment (Stern, 2004).

Since North Africa is a region made up of developing countries, it is intended to show this issue of destruction of the environment in this century (2000-2018) supported by the classical vision, where economic growth is considered subject to an increase in emissions of CO_2 to the atmosphere, as one of the main causes of global climate change. The contribution of this article is an analysis of the current environmental situation in North African countries, based on the revised methodological scheme, carrying out an individualized treatment of the data for each country.

The environmental consequences of economic growth have been studied many times before, with varying results. The objective of this study is to investigate if there is a relation between economic growth and carbon dioxide (CO_2) emissions. Will a richer economy worsen the environmental quality even further due to increased emissions, or will an increase in per capita GDP not only increase the living standards, but also contribute to a better, less polluted planet?

The level of environmental degradation is quantified as per capita carbon dioxide (CO_2) emissions. It is well known that CO_2 is one of the worst pollutants contributing to environmental issues (Houghton, 1996). Other pollutants causing environmental degradation are not included in this study; however, the theories used here could be applied for other pollutants as well. When measuring the economic status of a country, per capita gross domestic product (GDP) is normally used, as is this case. GDP is defined as the market value of all final goods and services produced in one period (Lequiller and Blades, 2006). Thus the research question of this study is as follows: is there a relation between per capita GDP and per capita CO_2 emissions?

This paper is divided into five sections, including the introduction, and organized as follows. The first section presents a brief review of international empirical literature on the relation between CO_2 emissions, energy consumption, and GDP. In the second, the methodology and data are shown. In the third section, the results

of the panel cointegration tests are presented, in addition to the estimates. Finally, the fourth and last section presents the conclusions.

2. Literature review

The measurement of environmental quality has its origin in the environmental curve proposed by Simon Kuznets (1955); through which the relation between carbon dioxide (CO_2) emissions and urbanization can be shown. The main reason for this theory is to demonstrate how the growth of the urban population affects the environmental quality of the countries through the level of CO_2 emissions. In this article, 141 countries were considered, classified according to their income, unlike most of the studies found which present analyses based on a single country.

Numerous researchers have studied the relation between energy consumption and GDP over the last thirty years, i.e. 1990-2020, however it is necessary to include CO_2 emissions in this case, given the growing environmental concern, due to the problem of climate change that occurs worldwide. Some of the most relevant works on this topic during the first decade of this century, are reviewed below.

Since the study by Panayotou (1993), empirical work on the question of the relation between economic growth and the environment has continued to abound. Indeed, Panayotou (1993) attempted, through both theoretical and empirical analysis, to verify the hypothesis of the Kuznets environmental curve (CEK), and in addition broadened the debate by urging those interested in the issue of the economic growth--environment relation to deepen their research to better identify its nature.

Despite the important role that environmental policies play in maintaining a balance between the market and the environment, the experience of implementing these types of policies in developing countries has shown adverse results. According to Panayotou (1994), environmental policies applied in developing countries are divorced from economic policy and environmental sustainability, a condition that remains, according to the results of various empirical studies (Agras and Chapman, 1999; Bringezu, Schütz, Steger, and Baudisch, 2004; Dinda, 2004; Lee et al., 2005; Sayed, 2013), where the increase of certain pollutants – carbon dioxide and monoxide, nitrogen oxides and sulfur, among others – puts forward a hypothesis of the destructive economic growth of nature.

Therefore, it is suggested that failures in the management, design and implementation of environmental policies are evidenced in the increase in environmental degradation, which in turn is an inevitable result of economic growth (Yaduma, Kortelainen, and Wossink, 2013). Empirical evidence shows that this hypothesis is fulfilled in South American countries, where the constant increase in CO_2 emissions, along with other pollutants, is largely explained by economic growth (Sayed, 2013; Suárez, 2011). In the academic environment this approach is represented through the Environmental Kuznets Curve (EKC), shown by an inverted U (Sayed, 2013), where the possible existence of a relation between environmental degradation

and economic growth is demonstrated (Lee et al., 2005; Stern, 2004). In addition, the estimates made for CO_2 emissions per capita (Apergis, 2016; Chng, Zhen Yang, 2019; Cho, Chu, and Yang, 2014; Farhani, Mrizak, Chaibi, and Rault, 2014; Galeotti, Lanza, and Pauli, 2006; Itkonen, 2010; Yang, Sun, Wang, and Li, 2015; Yin, Zheng, and Cheng, 2015; Shahbaz, Solarin, and Ozturk, 2016) indicate the presence of EKC in most of the countries analysed. However, Du et al. (2012) successfully rejected the Kuznets environmental curve (CEK) hypothesis. This result is confirmed by other authors, such as Chandran and Tang (2013), Saboori and Sulaiman (2013), Babu and Datta (2013), Zilio and Caraballo (2014), Özokcu and Özdemir (2017).

Cüneyt and Feyza (2018) studied the relation between CO_2 emissions, GDP, energy consumption, trade openness, financial development and institutional quality for 151 countries in the period 1996-2010, using the pooled ordinary least squares method. The results confirm the EKC hypothesis, where the relation between income and environmental degradation is an inverted U shape.

Işik, Ongan, and Özdemir, (2019) tested the EKC hypothesis for ten US states from 1980 to 2015, using an application of the heterogeneous panel estimation method. The results confirm the validity of the EKC hypothesis for Florida, Illinois, Michigan, New York, and Ohio. The results found negative impacts of fossil energy consumption on CO_2 emission levels in Texas, while there is a positive influence of energy consumption on CO_2 emissions in Florida but is lower compared to other states in the US.

Arifur et al. (2020) examined the EKC hypothesis for the BCIM-EC (Bangladesh–China–India–Myanmar economic corridor) member countries under the Belt and Road Initiative (BRI) of China. The results confirm that the EKC hypothesis exists in India and China, as well as in Bangladesh and Myanmar with regard to disregarding breaks within the short term.

Zhang, Jihuan (2021) tested the Environmental Kuznets Curve Hypothesis on CO_2 emissions for China in the period 1971- 2014, using ARDL model. The results indicate that there is an N-shaped relation between CO2 and GDP in the long run.

Cihan and Emrah (2021) tested the Environmental Kuznets Curve (EKC) in Australia using the Nonlinear ARDL Model with a Structural Break, for the period 1994 to 2014. The results confirm the validity of the EKC hypothesis.

3. Data and methodology

The testing of the EKC hypothesis for North African countries was carried out in this work through the annual time series dataset from 2000 to 2018. The data used came from the World Development Indicators (WDI). To measure environmental pollution, yearly CO_2 per capita in metric tons is extracted from the WDI, which is calculated by the Carbon Dioxide Information Analysis Center (the CO_2 series used in this study only include emissions from the burning of fossil fuels and the manufacture of cement). Annual real GDP per capita (constant 2010 US$) from the

WDI is used for the estimation as a proxy for income. Logarithms were applied to all variables to ameliorate heteroscedasticity issues.

Environmental management is essentially characterized by a technical, social, environmental, economic and political analysis (Munda et al., 1994). In the proposed case, an attempt was made to relate an economic component, growth, with an environmental one, i.e. CO_2 emissions, whose causal effects were validated through the analysis of the time series for 2000-2018 for each one of the North African countries considered – (Algeria, Morocco, Tunisia, Libya , Egypt, Sudan and Western Sahara) through the application of the Ordinary Least Squares method (OLS). This research, being of a quantitative nature, is based on a positivist philosophy in which it is assumed that there are social factors with an objective reality different from individual beliefs, focusing more on explaining the causes of change in social factors (Firestone, 1987). The quantitative analysis in the proposed scheme aims to identify general propositions that perform reasonably well in a series of cases, even as they manage to explain each particular case well (Mitchell, 2003).

In this study the two variables usually employed in the representation of the Environmental Kuznets Curve were considered: GDP per capita as an independent variable, and CO_2 emissions by energy sources expressed in metric tons per capita asa dependent variable, for the period from 2000 to 2018. In the case of GDP per capita, values expressed in dollars were taken at constant prices that have as the year reference 2010. A confidence level of 95% was assumed.

In the literature, various functions can be found that attempt to explain the relation between growth and environmental deterioration, the most common being the second-order polynomial, which demarcates a parable described by equation 1 (Dinda, 2004; Suárez, 2011)

$$ED_{it} = \alpha_i + \beta_1 X_{it} + \beta_2 X_{it}^2 + \beta_3 Y_{it} + \varepsilon_{it}, \tag{1}$$

where: *ED* equivalent to the indicator of environmental deterioration (CO_2 emissions), *X* is the GDP per capita, *i* identifies the country, *t* is the time value, *Y* is any other indicator that accompanies economic growth (for example, population), ε is the estimation error, α and β are equivalent to the coefficients that are kept constant in the model.

In equation 2, an accepted variant is shown for the representation of the EKC (Agras and Chapman, 1999), where the data of the time series are smoothed through the natural logarithm

$$lnED_{it} = \alpha_i + \beta_1 lnX_{it} + \beta_2 lnX_{it}^2 + \beta_3 lnY_{it} + \varepsilon_{it}. \tag{2}$$

The application of the OLS method through a system of simultaneous equations, one for each country, allows to identify those significant correlations under a statistically valid model, with conclusions of causality between the two variables

considered in the study. The adjusted functions applied in the proposed analysis in this case are as follows

$$CO_{2it} = \alpha_i + \beta_1 GDPP_{it} + \beta_2 GDPP_{it}^2 + \varepsilon_{it}, \quad (3)$$

$$lnCO_{2it} = \alpha_i + \beta_1 lnGDPP_{it} + \beta_2 lnGDPP_{it}^2 + \varepsilon_{it}, \quad (4)$$

where[1]: LCO_{2it} – CO_2 emissions *per capita*; $LGDPP_{it}$ – real GDP per capita; $LGDPP^2_{it}$ – real GDP per capita squared; ε_{it} – the error term.

4. Results

Table 1 shows the results obtained after applying the OLS method, considering equation 3. For the calculated parameter *t* for a $P < 0.05$, the author marked with an asterisk those coefficients that were not robust in the model proposed. A positive relationship between CO_2 emissions and GDP per capita can be observed in five of the seven countries analysed. The largest increases in CO_2 emissions were found in Algeria and Morocco, with increases that remain between 0.06 and 0.14 metric tons per year, and whose trends show that these levels could continue to grow over time. In these countries, GDP per capita explains the increase in CO_2 emissions.

Table 1. Results of the application of the OLS method cf. equation 3

Country	α	β_1	β_2	R^2
Algeria	4.8697 (2.861)	−0.0007 (−2.088)	5.27e−07 (2,495)	0.9376
Morocco	−0.9893 (−0.1691)	0.0006 (0.5907)	−7.86e−8 (−0.243)	0.7685
Western Sahara	3.1632 (2.761)	−0.0004 (−1.593)	3.26e−07 (1.748)	0.5852
Sudan	−1.873 (−0.6325)	0.0007 (0.9784)	−4.54e−07 (−0.715)	0.7506
Egypt	0.8043 (2.985)	−4.55e−04 (−0.6433)	3.41e−08 (0.6628)	0.0411*
Libya	−4.4637 (−2.106)	0.0012 (0.0276)	−3.55e−07 (−2.101)	0.8716
Tunisia	1.2087 (0.2107)	0.0007 (0.6794)	−3.3254 (−0.5589)	0.3512*

() – standard error of estimation; * R^2 is very low.

Source: author's elaboration.

[1] As is known, the parameters α_i, β_1, β_2 represent the long-term elasticity of CO_2 emissions with respect to $LGDPP_{it}$, $LGDPP^2_{it}$ respectively.

On the other hand, it can be observed that Tunisia and Egypt show non-significant correlations, indicating a case that is far from the traditional postulate of the EKC. Tunisia, in particular, presents a value of R^2 that is not conclusive according to the function considered, originating value $t = 2.363$ for $P < 0.05$. For both cases it is necessary to incorporate other indicators into the analysis to assess environmental deterioration and its relationship with economic growth.

Figure 1 shows the behaviour described by the function represented by the EKC in each of the cases analysed, highlighting the situation of Sudan and Libya, countries that could be contradicting the Kuznets hypothesis, which indicates that their development path has a positive proportional relation between CO_2 emissions and economic growth via GDP per capita. In these countries, there is a reduction in CO_2 levels from a higher GDP per capita increase of approximately US $ 9.600 and US $ 11.800 for Sudan and Libya, respectively.

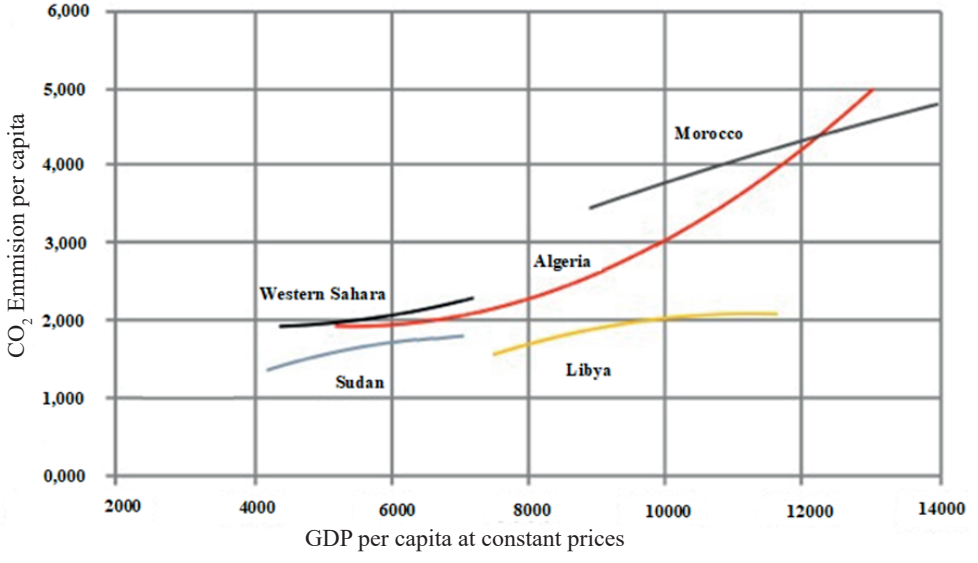

Fig. 1. CO_2 emissions per capita and GDP per capita by country

Source: author's elaboration.

A situation similar to the previous model is observed with the application of equation 4 (Table 2), maintaining the same analysis parameters used in equation 3. The model is statistically validated using the Breusch-Pagan test on the variance of the disturbances. In the case of equation 3, x2 = 50.875, with 36 degrees of freedom and P = 0.0512 were obtained. In equation 4, x2 = 49.858, with 36 degrees of freedom, and P = 0.0621 were obtained.

Table 2. Results of the application of the OLS method cf. equation 4

Country	α	β_1	β_2	R^2
Algeria	169.856 (2.573)	−37.746 (−2.718)	2.241 (2.682)	0.952
Morocco	−31.894 (−0.272)	6.362 (0.227)	−0.311 (−0.2463)	0.781
Western Sahara	122.864 (1.893)	−25.831 (−1.928)	1.577 (1.991)	0.579
Sudan	−79.849 (−0.654)	16.816 (0.596)	−0.944 (−0.583)	0.792
Egypt	25.689 (0.795)	−6.224 (−0.842)	0.339 (0.818)	0.061*
Libya	−159.629 (−1.704)	31.892 (1.711)	−1.772 (−1.661)	0.861
Tunisia	−38.863 (0.514)	8.175 (0.513)	−0.514 (−0.509)	0.371

() – standard error of estimation; * R^2 is very low.

Source: author's elaboration.

5. Conclusions

The main conclusion of the study mainly shows that GDP per capita reflects the influence of changes in the level of income on environmental pollution, contributing to the criticism in the sense that the social and economic system is inherent to the destruction of the environment (Levy, 1997).

The thirst for economic growth has inevitably increased the consumption of natural resources and the pressure to protect the environment (Yang, Yuan, and Sun, 2006), with North Africa being a palpable case of environmental deterioration in support of economic activity.

Just as with some developing countries in America and Asia, the problem in the North African region could derive from a failure in environmental policies and a commitment to conscious environmental management, with problems that could be extended to other indicators of environmental deterioration, such as deforestation and the emission of other pollutants (Chowdhury and Moran, 2012). In this study, the result was similar to that reached by Galindo (2010, p. 69), allowing for the conclusion that "the projections made allow us to assume that emissions per capita in the region will continue to increase in the form of an absolute convergence process ...".

Despite the above, the region could not be treated as a universal theoretical or empirical case, since there could be particular cases between countries where the effects could be contrary to those expected (Barrett, Bulte, Ferraro and Wunder, 2013), as is the case of Tunisia and Egypt. According to Zapata (2011, p. 73), this

could be the opportunity to promote investments that catalyse and support "selective public spending, political reforms and changes in regulation", in order to reverse the trend in the increase in emissions of carbon dioxide. The degradation of the world's natural system requires an appropriate policy response (Barrett et al., 2013). For Yang et al. (2006), the empirical study shows that economic growth and environmental protection can be coordinated.

It is proposed to include in future research some additional variables related to other measures of pollution other than CO_2 emissions, cf. Panayotou (1991), who states that not all the variables would have an explanation in GDP per capita.

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ANALIZA EMPIRYCZNA ŚRODOWISKOWEJ KRZYWEJ KUZNETSA WZROSTU GOSPODARCZEGO I EMISJI CO_2 W KRAJACH AFRYKI PÓŁNOCNEJ

Streszczenie: Celem pracy było zbadanie związku między wzrostem gospodarczym a emisją dwutlenku węgla (CO_2) w krajach Afryki Północnej w latach 2000-2018. Aby to udowodnić, autor zastosował metodę OLS dwóch zmiennych opisujących środowiskową krzywą Kuznetsa: PKB *per capita* i CO_2. Wyniki pokazują, że PKB *per capita* odzwierciedla wpływ zmian poziomu dochodów na zanieczyszczenie środowiska w pięciu z siedmiu badanych krajów.

Słowa kluczowe: emisje CO_2, wzrost gospodarczy, środowisko, podejście kointegracji paneli.