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CO2 emissions, renewable energy and the Environmental Kuznets Curve, a panel cointegration approach

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ABSTRACT

This study combines a panel cointegration analysis with a set of robustness tests to assess the short and long-run impacts of renewable energy on CO2 emissions, as well as the Kuznets Environmental Curve hypothesis for 25 selected african countries, over the period 1980-2012. The results provide no evidence of a total validation of EKC predictions. However, CO2 emissions are found to increase with income per capita. The overall estimations strongly reveal that renewable energy, with a negative effect on CO2 emissions, coupled with an increasing long-run effect, remains an efficient substitute for the conventional fossil-fuelled energy. Nonetheless, the impact of renewable energy is outweighed by primary energy consumption in both the short and long run, entailing more global synergy for outpacing the environmental challenges.

1. Introduction

The 2015 Paris conference on climate change appears as a watershed mark in the efforts of the international community to grapple with global warming through reducing greenhouse gases emissions. In spite of the mobilization and determination showed by governments over decades, at the actual rate of CO2 emissions, the temperature of the planet will still remain above the threshold of 2 °C set by scientists [47]. The alarming fact is that the temperature is projected to reach 3^0C by 2050 [47], increasing the risk of natural disasters, and creating more pressure on resources [24]. According to the IPCC [24], if no sustainable adaptation policy is implemented, the impact of climate change would reduce the annual GDP growth in developing countries as much as 2–4% by 2040, and 10% by 2100. The common global agenda putative by nations is to compel developed countries to implement more environmental friendly energy policies (through standard settings, nuclear energy, etc.), and help developing countries to reduce their CO2 emissions, without jeopardizing their economic progress. Among these energy policies, actions such as environmental fund transfers to developing countries, renewable energy, and technology transfer can help developing countries to take part in the world's environmental challenge [22,48].

Although Africa pollutes less than other continents, it is the most severely affected by global warming. According to the IPCC [24], with around 50% of the urban population and nearly 10% of the rural population accessing electricity, the increase in urbanization, combined with the reduction in crop yields due to climate change, and the high migration from rural to urban areas would constitute one the most challenging issues for sub-Saharan Africa in the energy sector. This paper investigates the role of Africa in global warming by analyzing the efficiency of an environmental policy suitable for developing countries, which is spreading across Africa and perceived as the path to sustainable growth in Africa [24], namely renewable energy. According to the International Renewable Energy Agency [23], energies generated from sources such as wind, solar, and hydro can help boost friendly environmental development in Africa in the sense that they are inexhaustible and free. Their deployments can create jobs, contribute to the improvement of local skills, and they are good pathways for income generating activities [23].

Two main features distinguish this paper from previous research on the topic, and contribute to filling the gap in the literature. First, the topic is focused solely on Africa. The majority of papers on CO2 emissions concentrate either on developed countries or on both developed and developing countries. For example, Baek and Kim [6], Apergis and Payne [2], and Ibrahim and Law [20] have analyzed, respectively, G-20 countries, 6 Central American countries and 69 countries (including developed and developing countries). In their research, they have found that energy consumption increases CO2 emissions. Apergis et al. [3] have analyzed 19 developed and developing economies, and have found that nuclear energy has a negative effect

Abbreviations: ASEAN, Association of Southeast Asian Nations; CCEEM, Common Correlated Effects Estimator; EKC, Environmental Kuznets Curve; EIA, Energy Information Administration; IPA, International Energy Agency; IPCC, Intergovernmental Panel on Climate Change; IRENA, International Renewable Energy Agency; MRIO, Multi-Regional Input–Output; OECD, Organization for Economic Cooperation and Development; PSTR, Panel Smooth Transition Regression; STIRPAT, Stochastic Impacts by Regression on Population, Affluence and Technology

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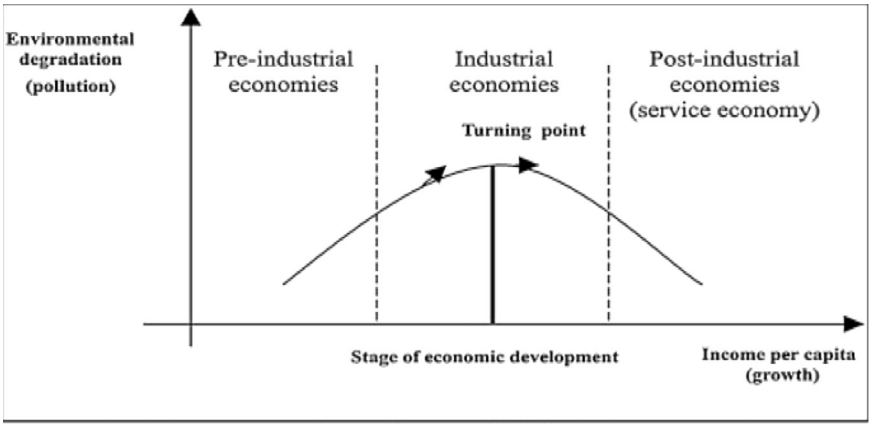

Source: Panayotou [46]

Environmental Kuznets Curve

Fig. 1. Development process and pollution: The Environmental Kuznets Curve.

on CO2 emissions while energy consumption has a positive impact. Although Africa has comparatively less CO2 emissions (which could be the reason why the majority of the studies have omitted the continent), it is important to measure, on one hand, the continent's contribution to global warming; and, on the other hand, the effectiveness of policies such as renewable energies. Second, the paper analyzes the long-term effectiveness of renewable energy and its cointegration with population growth, energy consumption and income per capita, using a panel cointegration approach. Although research on the mitigation of global warming has been driven toward nuclear energy as a potential strategy for reducing the carbon footprint, in Africa, nuclear energy is in not an ideal option due to the long lead times, governments disapproval and the high capital cost, as pointed out by Apergis et al. [3]. Furthermore, the panel cointegration analysis used in this paper appears more appropriate than the methods commonly used in the literature, such as VAR, VEC, panel random and fixed effect or Autoregressive Distributed Lag (ARDL) (Fig. 1).

Unlike traditional time series or panel data analyses, panel cointegration has an advantage of pooling the long run information included in the panel, by allowing the short run dynamics and fixed effect to be heterogeneous across the panels [39]. In addition, the t-statistic allows for a more flexible alternative hypothesis [37].

Additionally, the paper assesses the hypothesis that pollution increases as income rises up to a threshold point, then starts decreasing. The inverted U-shape of the relationship income-pollution refers to the EKC, initiated by Kuznets [29] to explain the relationship growth-income inequality, and adapted by economists since 1991 in the context of environmental degradation.

According to the EKC, there are three stages in the intensity of pollution. Each stage corresponds to a step in the growth process. At the pre-industrial stage where income per capita is low, environment pollution increases. This increase in pollution is explained by factors such as unclean technology used in economic activities, lack of awareness, prioritization of income growth and profits at the early stage of growth [51]. However, with the increment in income per capita and economic growth, followed by improved social indicators, more investments are made for safer technologies, households become more willing to target their expenditures towards cleaner goods and assets (water, houses, cars, etc.). This stage marks the turning point to lower environment pollution. As the economy crosses the pre-industrialization stage and moves to the post-industrialization phase, environmental depletion reduces [35]. The folowing graph summarizes the EKC insight.

1.1. Environmental Kuznets Curve

Tremendous efforts have been made by researchers to analyze and understand the potential factors that can explain the CO2 footprint and its mitigation (with no harm on development). Although the recent literature tends to move towards the importance of nuclear energy in mitigating greenhouse gas emissions (such as Baek and Pride [7]; Apergis, et al. [3]; Menyah and Wolde-Rufael [33], to name just a few), many studies have paid attention to the potential impact of renewable energy in greenhouse gas emissions as well as other relevant sources of pollution such as energy consumption, and population growth. Table 1 summarizes some of the most cited studies.

2. Data and methodology

The study covers 33 years (1980–2012) and 25 countries for a total of 825 observations. The selection of countries is mainly based on the availability of data, and the existence of significant renewable energy initiative (reflected in the data) such as wind, solar, hydropower, geothermal, and heat pumps. The list of variables includes CO2 emissions in metric ton per inhabitant, as a proxy for air quality; real GDP per capita in USD (constant 2005); per capita primary energy consumption (converted into kg of oil equivalent); total renewable electricity net consumption per capita (in kilowatt-hour) as a proxy for renewable energy. Renewable electricity comes from 5 main sources: hydro-electric power, geothermal, solar, wind and biomass such as wood, wastes and biofuels [16]. To test the effect of demography on CO2 emissions, the variable population growth is added. While the variables CO2 emissions, renewable energy and energy consumption are collected from EIA. The African Development Indicators database (available in the World Bank databank) provides data on population and real GDP per capita. Table 2 presents a summary statistics of the variables.

3. Methodology

3.1. Equation specification

The baseline equation for this study is the equation specified by previous studies such as Iwata, et al. [25]. In their study, the authors have used an ARDL approach to assess the EKC hypothesis and the role of nuclear energy in mitigating CO2 emissions in France. The log-linear equation specified is as follows:

$$\ln (CO_2)_t = \alpha_0 + \alpha_1 \ln y_t + \alpha_2 (\ln y_t)^2 + \alpha_3 \ln nuc_t + \varepsilon_t \quad (1)$$

where CO_2 represents CO2 emissions per capita; y real GDP per capita;