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Energy consumption, economic growth and carbon emissions: Cointegration and causality evidence from selected African countries

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ABSTRACT

This paper examines the long-run and causal relationships among energy consumption, carbon dioxide (CO2) emissions and economic growth for a sample of 12 selected Sub-Sahara African countries. It applies the bounds test to cointegration and Granger causality test to annual data covering the period 1971–2010. The empirical results are mixed across countries. In the long-run, energy consumption and economic growth are associated with increase in atmospheric pollution in most countries. Results from the Granger causality tests show evidence of economic growth causing CO2 emissions in the short-run in Benin, Democratic Republic of Congo, Ghana, Nigeria and Senegal, implying that economic expansion cannot be achieved without affecting the environment. Evidence of reverse causality running from CO2 emissions to economic growth has been found for Gabon, Nigeria and Togo, indicating that environmental policies aiming at reducing air pollution may have adverse effects on economic growth. Moreover, bidirectional causality between economic growth and CO2 emissions has been found in the short-run for Nigeria and in the long-run for Congo and Gabon. In the long-run, energy consumption and economic growth cause CO2 emissions in Benin, Cote d'Ivoire, Nigeria, Senegal, South Africa and Togo.
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1. Introduction

Greenhouse gas emissions, especially carbon dioxide (CO2) emissions, are considered to be the main cause of global warming. In order to prevent global warming and its consequences, several countries have signed the Kyoto Protocol and promised to decrease their emission levels. Recently, the 21st session of the United Nations Conference of the Parties (COP21) held in Paris in December 2015 is a major milestone in efforts to reduce greenhouse gas emissions and combat global warming. This calls for a clear identification of the sources of CO2 emissions. A growing empirical literature has investigated this topic. Results from this literature are however mixed across countries, energy variables and modeling techniques. Some studies found that pollution level increases as a country develops, but decreases as income exceeds a threshold level, providing support to the so-called Environmental Kuznets Curve (EKC) (see Refs. [14,21,34,40,16]). However, many other works found more ambiguous results implying that EKC may not hold at all times and for all pollutants (see Refs. [41,48]).

Moreover, most existing studies focus either on the nexus of output-energy ([9,49,4]; among others) or output-pollution ([15,46,47]; among others). But little effort has been made to test these two links in the same framework. This study is an attempt to fill the gap in the case of Sub-Sahara African countries. Sub-Saharan Africa is an interesting case study for this topic given that air pollution is now becoming a subject of great concern for policy makers and environmentalists. Indeed, more than 75% of the population in Sub-Saharan Africa relies on energy sources which are polluting and indoor air pollution associated with solid fuels use is responsible for more than 4000 premature deaths per day [23]. The choice of this region is also motivated by the fact that despite the burgeoning literature on the relationship between output, energy consumption and pollution, very few studies have been conducted for Sub-Sahara African countries.

This paper aims to investigate the relationships between energy use, economic growth and carbon dioxide emissions for 12 Sub-Sahara African countries. Hence, data series from the World Bank's 2014 *World Development Indicators* are used and cover the period 1971–2010. The main contributions of the paper are

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threefold. First, in terms of econometric methodology, the study uses the bounds test for cointegration developed by Ref. [38] to overcome many shortcomings of alternative methods commonly used in the empirical literature. The bounds test has been widely used in many empirical studies (see Refs. [3,12,25,28,37]). However, an important innovation in applying this technique in this paper is the computation of 'exact' critical values. This is an important issue given that existing critical values are based on large sample sizes. Second, regarding the sample of countries under study, all Sub-Sahara African regions are covered, namely West Africa, East Africa, Southern Africa and Central Africa. This sample is different from those used by recent studies on African countries, such as Refs. [3,19,28]. Moreover, the sample size in this paper is larger than those used in previous studies. Third, a country-by-country case study is employed as it is more promising in terms of policy recommendations than a panel or cross-sectional approach. As well pointed out by Refs. [18,45,9] the absence of consensus in the empirical literature can be attributed to the heterogeneity in climate conditions, varying energy consumption patterns and the structure and stage of economic development among countries.

2. Literature review

The relationship between energy, the environment and economic growth has received increasing attention in recent years. From a theoretical point of view, Jorgenson and Wilcoxen [27] provide an interesting work that focuses on modeling interrelationships between energy, the environment and economic growth through an intertemporal general equilibrium framework. This relationship seems to be dynamic as discussed by Ref. [29] because while resource use yields immediate economic benefits, its negative impact on the environment may be observed in the long run.

Apart from the works on the direct link among these three variables of interest, the economic analysis of sustainable development and environmental policy has gained new impetus from endogenous growth theory. For example, Brock and Taylor [13,14] present a theoretical framework to explain the Environmental Kuznets Curve (EKC) throughout a Solow model. When they incorporate technological change in abatement into the Solow model, the EKC is a necessary by-product of convergence to a sustainable path. Recently, Ricci [40] provides a theoretical survey about channels of transmission through which environmental policy and economic growth interact. This may be partly due to some models treating pollution as an input to production, and others as a negative by-product.

Regarding the policy effects, Ricci [40] indicates that environment policies impose constraints on the production possibilities set. In this line, they have negative effects on economic growth. However, if environment improvement results in increased factor productivity and stimulates innovation, the growth prospects will be enhanced. Furthermore, expectations of a better environment may encourage saving. Consequently, the energy-environment-growth relationship may be dynamic. Most of theoretical studies mention that any effective policy (pollution taxes, emissions trading, conservation) should take the dynamic nature of the relationship between energy, the environment and economic growth into account and should have a long-run vision ([43]).

Empirically, many studies investigated since the last two decades the association between carbon dioxide (CO2) emission, energy consumption and economic growth. Most of these studies have focused on the precedence of these three variables using various non-causality tests. In this line, Coondoo and Dinda [15] analyse the causal relationship between GDP and CO2 emission in country specific panel data. Applying fixed effect specification and within regression method they find that there is a one-way causality from CO2 emission to real GDP per capita for North America, Western Europe and Eastern Europe, a one-way causality from real GDP per capita to CO2 emission for Central and South America, Oceania and Japan and a two-way causality for Asia and Africa. Ang [6] examines the dynamic causal link among the environmental quality, energy use and output in France. She argues that these variables are interrelated and evidences that economic growth causes energy consumption and pollution in the long term, and uni-directional causality, in the short term, from energy use to output growth. Ang [7] concludes that output growth Granger causes energy consumption in Malaysia during the period 1971–1999. However, weak evidence of causality running from carbon emissions to income in the long run, but no feedback link is evidenced. Following Refs. [6,7] dynamic analysis on the relationship between energy, the environment and economic growth, Marrero [32] considers data on 24 European countries over the period 1990–2006 and builds a dynamic panel model. She finds no evidence in favour of the EKC hypothesis due to the transition experienced by the countries of the East and which has resulted in a drastic reduction in their emissions.

Ref. [8] use a system of dynamic panel model comprising real gross domestic product, nuclear energy consumption, renewable energy consumption, and total carbon dioxide emissions based on data about OECD countries, emerging and developing countries from 1984 to 2007. Their results suggest that nuclear energy consumption plays an important role in reducing CO2 emissions whereas renewable energy consumption does not contribute to reductions in emissions in the short term. Soytas et al. [44] apply a multivariate model with income, energy consumption, carbon emissions, gross fixed capital formation, and labour force, and find no causality between income and carbon emissions, and no causality among energy use and income in the USA. But in the long-run, there is enough evidence of causality running from energy consumption to the carbon emissions. Following Refs. [43,44] find the same results about the link between income and carbon emissions in Turkey.

However, there is a unidirectional causality running from carbon emissions to energy consumption in the long run. The lack of long run causality between income and carbon emissions provides evidence that both USA and Turkey can reduce carbon emissions without forgoing economic growth. Halicioglu [22] provides a more robust econometric framework, with carbon emissions, energy use, income, and foreign trade, and finds a bi-directional Granger causality between the carbon emissions and income in Turkey, in short and long run. This result is conflicting with that of Soytas and Sari [43]. Zhang and Cheng [51] use the Toda and Yamamoto methodology to investigate the relationship between energy consumption, economic growth and carbon emissions in China. They find unidirectional long-run causality running from economic growth to energy consumption and from energy consumption to carbon dioxide emissions. Their results show that neither carbon emissions nor energy consumption contribute to economic growth. Lean and Smyth [30] use panel data on ASEAN and report evidence of short-run Granger-causality from CO2 emissions to electricity consumption and long-run causality from electricity consumption and CO2 emissions to economic growth.

Recent studies by Ref. [1] propose an interesting and novel approach that may detect causality when time-constant hypothesis is rejected using data series on G7 countries. While they find significant time-varying causalities running from GDP to CO2 emissions for Italy and Japan, the finding of inverted N-shaped curves (Italy and Japan) lends no support to the traditional Environmental Kuznets Curve hypothesis for these countries. These results are consistent with studies by Ref. [37] for a sample of developed,

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