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Analysis of asymmetries in the nexus among energy use, pollution emissions and real output in South Africa

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ABSTRACT

This study examines asymmetries in the nexus among energy use, pollution emissions and real output in South Africa using a nonlinear ARDL model advanced by Shin et al. [48]. The findings suggest the presence of asymmetries in the nexus among the indicated variables in the short and long run. Negative and positive shocks of the variables have different effects in sign and magnitude. The findings further show that both energy use and CO2 emissions affect real output; therefore caution is needed when advocating energy and environmental policies in South Africa, and the presence of asymmetries in the relationships among these variables should be taken into account. Further studies are needed to shed more light on asymmetries in the nexus among these important variables.

1. Introduction

Energy consumption, although a crucial factor in the growth and development process of economies, leads to pollution emissions causing global warming and climate change which is an issue of global concern [41]. According to the Energy Information Administration (EIA), the world energy consumption increased by more than 45% in the last three decades causing a rise in carbon dioxide of (CO2) emissions by 40%. This harms the green space and inflicts irreparable damages to the atmosphere which in turn results in droughts, floods, tornadoes, rising sea levels, and melting of glaciers, etc. as consequences of climate change [17].

South Africa, which is the focus of this study, is the biggest energy consumer in Africa. Out of 379.6 quadrillion Btu[1] that Africa consumed during the period 1980–2012, South Africa alone consumed 142.2 quadrillion Btu,[2] that is, 37.4%. While this has brought some output gains since South Africa is the biggest economy in the region, it has also caused some environmental damage. South Africa is actually the biggest source of pollution emissions in Africa; out of 28096.93 Million Metric Tons of dioxide of carbon (CO2) emitted by Africa for the period 1980–2012, South Africa emitted 12037.96 Million Metric Tons of dioxide of carbon (CO2),[3] that is, 42.8%. In fact, it is said that air pollution in South Africa in industrial hubs has gone beyond the WHO (World Health Organization) recommended limits.[4]

There is need to reduce energy consumption in order to cut down pollution emissions. However, to propose an adequate energy policy or environmental policy, it is necessary to analyze the nexus among energy consumption, pollution emissions and output. It should be noted that analyzing the relationships among these variables is important for policy implication; if for instance energy

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[1] British thermal units.

[2] Data information is from the International Energy Statistics (Online Database).

[3] Data information is from the International Energy Statistics (Online Database).

[4] http://www.enca.com/sa-air-pollution-exceeds-who-limits.

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consumption and pollution emissions are found not to affect output, then energy conservation and efficiency improvement policies can be applied to reduce energy use and pollution emissions without affecting economic growth [4].

Analyzing the relationships among energy consumption, pollution emissions and output level has been the subject of considerable research in the past decades. According to Wang [53]; CO2 emissions are directly related to the use of energy which is an essential factor in both production and consumption. CO2 emissions can be from electricity and heat production, gaseous fuel consumption, liquid fuel consumption, solid fuel consumption, manufacturing industries and construction, transport, residential buildings, and commercial and public services, etc. An increase in energy consumption leads therefore to an increase in CO2 emissions.

On the relationship between pollution emissions and output level, higher level of carbon dioxide emissions leads to climate change, reducing hence the productive capacity of a country [15], which suggests a negative impact of pollution emissions on output. However, on the other hand, economic activities need higher amounts of energy consumption hence carbon dioxide emissions. In this case, an increase of CO2 emissions caused by an increase in energy consumption leads to an increase in output level.

In explaining the nexus between energy use and real output, four hypotheses are found in the literature; the growth hypothesis, the conservation hypothesis, the feedback hypothesis and the neutrality hypothesis [7,8]. For the growth hypothesis, there exists a positive causal effect of energy consumption on real output; reducing energy consumption will have an adverse effect on real output, energy conservation policies are to be applied with caution in this case. In contrast, for the conservation hypothesis, causality runs from real output to energy consumption, implying that energy conservation policies would have little or no impact on output level. In the feedback hypothesis, causality between energy consumption and real output is bidirectional; in this case, energy consumption and real output affect each other simultaneously. An increase in energy use causes an increase in real output and vice versa. Lastly, the neutrality hypothesis suggests an independent relationship between energy consumption and real output; energy conservation policies would have no effect on output level.

Empirical studies abound on the relationships among energy consumption, pollution emissions and real output. Some studies focus only on the relationship between energy consumption and real output (see, for instance, [3,5,7,8,14,16,18,19,23,28,31,32,33,37,40,45,49,54]), others discuss the nexus between pollution emissions and economic growth to test the Environment Kuznets Curve (EKC) hypothesis (see, for instance, [20–22,34,38,29,53]).

Xia [55] however points out that due to the interaction among the three variables, energy consumption, CO2 emissions and real output, separating them can be misleading when analyzing the links among them. According to Xia [55]; it is impossible to separate the impacts of energy consumption and pollution emissions on real output. Thus, studies have also examined the interactions which exist among the three variables, energy consumption, CO2 emissions and real output (see Refs. [1,2,6,9,11,24,30,36,39,42,43,47,50,51,56]).

Hatemi-J and Uddin [26] bring to light an issue that has been neglected in the literature, that is, to allow for asymmetry in the investigation of the causal relationships among energy consumption, CO2 pollution and real output. According to Hatemi-J and Uddin [26]; allowing for asymmetry is important because the effect of a negative shock of a variable can be different from the effect of a positive shock in sign and magnitude. In addition, allowing for asymmetry is made possible by new techniques available now Hatemi-J [27]; for the transformation of data into cumulative sum of positive and negative components Hatemi-J [25], for asymmetric causality tests and Shin et al. [48] for asymmetric ARDL modeling.

The novelty of this study is in allowing for asymmetry while examining the nexus among energy use, CO2 emissions and real output using a nonlinear ARDL model, a recent innovative methodology advanced by Shin et al. [48]. We analyze this issue for the case of South Africa as the biggest energy consumer, biggest source of pollution emissions and the largest economy in Africa.

The rest of the paper is organized as follows. Section 2 highlights the methodology. Section 3 presents and interprets the empirical results and section 4 concludes the study.

2. Methodology

To examine asymmetries in the nexus among energy use, CO2 emissions and real output, this paper uses a nonlinear ARDL model (NARDL) developed by Shin et al. [48]. Given two non-stationary variables I(1), y_t and x_t, their starting point is the following asymmetric long-run regression:

$$y_t = \beta^+ x_t^+ + \beta^- x_t^- + u_t, \tag{1}$$

where β^+ and β^- are the associated long-run parameters, and x_t^+ and x_t^- are partial sum processes of positive and negative changes in x_t defined as follows:

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} \max(\Delta x_j, 0); x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} \min(\Delta x_j, 0) \tag{2}$$

Shin et al. [48] associate equation (1) with the linear ARDL model of Pesaran et al. [46] and obtain the following nonlinear ARDL model:

$$\Delta y_t = \rho y_{t-1} + \theta^+ x_{t-1}^+ + \theta^- x_{t-1}^- + \sum_{j=1}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{j=0}^{q-1} \Big(\pi_j^+ \Delta x_{t-j}^+ + \pi_j^- \Delta x_{t-j}^- \Big) + e_t, \tag{3}$$

for $j = 1, \ldots, q-1$, with $\beta^+ = -\theta^+/\rho$ and $\beta^- = -\theta^-/\rho$.

From the nonlinear ARDL model in equation (3), Shin et al. [48] suggest two tests for asymmetric cointegration, namely the *t*-test of Banerjee et al. [13] and the F-test of Pesaran et al. [46]. The *t*-test of Banerjee et al. [13] denoted t_{BDM} tests the null hypothesis that $H0: \rho = 0$ against the alternative hypothesis that $H1: \rho < 0$, while the F-test of Pesaran et al. [46] denoted F_{PSS} tests the null hypothesis that $H0: \rho = \theta^+ = \theta^- = 0$. Long-run symmetry restrictions can also be tested by imposing $\theta^+ = \theta^- = 0$ while short-run symmetry restrictions are tested by imposing $\pi_j^+ = \pi_j^-$ for all $j = 0, \ldots, q-1$ or $\sum_{j=0}^{q-1} \pi_j^+ = \sum_{j=0}^{q-1} \pi_j^-$. From equation (3) and following Katrakilidis and Trachanas [35]; and Athanasenas et al. [12]; the general form for the nonlinear ARDL (*p*, *q*) model of energy use (*eu*), CO2 emissions (*co2*) and output (*y*), can be written as: