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Investigating the relationship between electricity consumption and economic growth: Evidence from South Africa

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ABSTRACT

This paper explores the causal relationship among electricity consumption, economic growth, financial development and CO_2 emissions for South Africa over the period 1971–2012. The Autoregressive Distributed Lag (ARDL) bounds test is used to test for the presence of cointegration, whereas the Toda and Yamamoto augmented Granger causality test is used for direction of causality. The results of ARDL-bounds test validate the existence of cointegration among the included variables. Further, the Toda and Yamamoto Granger causality test affirms that there is no causality between electricity consumption and economic growth. This signifies that neutrality hypothesis holds for South Africa during the period under the study. Additionally, there is a unidirectional causality running from CO_2 emissions to electricity consumption as well as a unidirectional causality running from financial development to CO_2 emissions. The empirical finding suggests that policy-makers should establish concrete plans to increase investment in the electricity sector to ensure reliability of supply. Moreover, policy-makers need to address the pressing environmental concern by tapping into the sizeable renewable energy potential of the country. Consequently, it will assist in promoting sustainable economic growth and development.

1. Introduction

South Africa's economy has long been considered one of the largest and most diversified economies in Africa [1]. The country's path to development has been based heavily on capital and energy-intensive development supported by abundant resources. Despite the country having limited proven oil and gas resources, it uses its large deposits of coal to sustain its energy needs. In 2013, 72% of South Africa's total primary energy consumption came from coal, followed by oil (22%), natural gas (3%), nuclear energy (3%) and renewable energy, less than 1% [2]. The abundant supply of natural resources, most notably coal has been instrumental in the energy sector. For example, currently more than 85% of South Africa's electricity is generated from coal-fired power stations, 10% from hydroelectric plants, 4% from nuclear powered plants and 1% from non-hydro renewable energy [2].

Recently, South Africa has been grappling with deep-rooted problems in the electricity sector as well as environmental issues. The most concerning issue in the electricity sector is the shortage of electricity supply. Tight supply and demand balance are caused by several intertwined problems that are still not being resolved fully. To begin with, there has been decreasing reserve margin in the electricity sector. Since the late 1990s to 2000s not much was done to resolve the margin shortages [3]. As electricity demand grew, no new capacity was added to the electricity sector and the electricity system reliability was allowed to deteriorate unchecked [3]. The combination of lack of added electricity capacity and decreasing reserve margin resulted in nation-wide blackout in 2005, 2007 and as recently as 2014. Additionally, structural inefficiencies continue to pose a threat to the electricity sector. The main cause of structural deficiencies in the electricity sector is due the abundance of municipal distributors that are poorly-run and poorly-managed [4]. It is estimated that the problems in the electricity sector have cost the local economy around 10% of GDP [5]. Additionally, South Africa's record of Greenhouse gas (GHG) emissions is poor. In 2009, South Africa's total GHG amounted to a staggering 547 million tons, which represents a 20% increase since 2000 [6]. Furthermore, South Africa is one of the world's largest emitter of CO_2 in the world and it is directly responsible for almost half of the CO_2 emissions for the entire African continent. CO_2 emissions increased by 24.3% from 2000 to 2010 and the energy sector was the largest contributor [7]. Given this record, South Africa is under considerable

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pressure to reduce its greenhouse emissions [5].

It is against the aforementioned facts that the motivation to re-examine the causal relationship between electricity consumption and economic growth arose. The results of such a study have significant bearing on energy policy for SA. The broad objective of this paper is to analyze empirically the causal relationship between electricity consumption, economic growth, financial development and carbon dioxide emissions. This study is different from other studies in three folds. Firstly, this study employs a multivariate framework in contrast to most prior studies on SA that employ bivariate or at most trivariate frameworks. Using a multivariate framework will avoid biased and inconsistent results caused by the omission of relevant variables [8,9]. Secondly, to our knowledge, no other study has used the aforementioned variables to study the electricity consumption-growth nexus for South Africa. Finally, this study uses longer period data in order to verify the long run relationship among the incorporated set of variables. In the process of achieving the objectives, long-run relationship among the variables is tested using ARDL bounds test and causality is tested using Toda and Yamamoto [10] augmented Granger causality test.

The rest of the paper is structured as follows: Section 2 deals with relevant literature review. Section 3 presents the empirical methodology and data used in this study. Section 4 interprets empirical results. Section 5 concludes the paper.

2. Literature review

The energy/electricity-economic growth nexus field has been an established field for several decades and continues to be an area of active research. Recent advances in applied econometric estimation methods have been a key reason for the growth of empirical research in the field [11]. However, despite the advances in the field, results on causality vary substantially from study to study. The variation in results also extends to studies conducted on the same country. The literature on the relationship between energy consumption and economic growth can be traced back to Kraft and Kraft [12]. In their influential paper they investigated the causal relationship between Gross Energy Consumption (GEC) and Gross National Product (GNP) for the U.S using Sim's causality. They uncovered evidence of unidirectional causality running from GNP to GEC without feedback. However, Akrarca and Long [13] reinvestigated the causality and they pointed out that the results obtained by Kraft and Kraft is spurious, and there is no evidence of causality. After the Kraft and Kraft study, several authors became involved in the debate to either challenge the results of Kraft and Kraft or to support the results [14]. Due to the vast volume of studies available, it is possible to divide the studies into four competing hypotheses [11,15]. The first hypothesis maintains that energy consumption causes economic growth (Growth hypothesis). The second hypothesis states that growth causes energy consumption (Conservation hypothesis). The third hypothesis asserts that energy consumption and growth are interrelated (Feedback hypothesis). The fourth hypothesis, known as the neutrality hypothesis assumes that there is no established link between energy consumption and growth. A selection of recent studies is presented in Table 1.

The studies conducted on South Africa investigates the nexus between electricity/energy consumption and growth either individually or within a group of other countries. With regards to the studies conducted on South Africa specifically, Odhiambo [16] analyzed the causal relationship between electricity consumption and economic growth for South Africa for the period 1971–2006. The author added employment rate to the model to create a trivariate framework. The result of the Granger causality test point towards a bidirectional causality between electricity consumption and economic growth. Based on the results, the author recommended that policies that were aimed at expanding the electricity infrastructure should be intensified. Furthermore, Dlamini, Balcilar, Gupta & Inglesi-Lotz [17] investigated the causality between electricity consumption and economic growth for South Africa using bootstrap rolling Granger non-causality test. The authors found that for two periods, 2002–2003 and 2005–2006 there was evidence of growth hypothesis. They further point out that apart from the two periods, Granger causality is weak for most of the sample period. The authors assert that energy saving policies that are aimed at reducing the level of carbon emissions will not affect economic growth. Continuing with South Africa specific studies, Menyah and Wolde-Rufael [9] examined the causal relationship between economic growth, pollutant emissions and energy consumption for South Africa for the period 1965–2006. Based on the results of modified Granger causality, the authors uncovered a unidirectional causality from energy consumption to economic growth.

In terms of multi-country studies that included South Africa, Cowan et al. [18] investigated the causal link between electricity consumption, economic growth and CO_2 emissions for the BRICS countries. For South Africa, the results indicated that there is a unidirectional causality from economic growth to electricity consumption for the period 1990–2010, thus favoring conservation hypothesis. The authors concluded that for South Africa, energy conservation policies will have little or no adverse effect on economic growth. Odhiambo [19] examined the causal relationship between energy consumption and economic growth for three sub-Saharan African countries. The results of ARDL-bounds testing procedure point towards a unidirectional causal flow from energy consumption to economic growth for South Africa during the period 1972–2006. Furthermore, Wolde-Rufael [20] examined the long-run and causal relationship between electricity consumption and economic growth for 17 African countries for the period 1971–2001. The results for South Africa indicated that there is no causality between the variables. The results of Wolde-Rufael [20] is further corroborated by Ahmed and Azam [21] despite using a slightly longer time period (1971–2011). From the South African studies, it is instructive to note that majority of the studies have included South Africa with a group of other countries such as [19,20,22]. Grouping countries together in a study will not adequately address the country specific effects of energy/electricity consumption on economic growth and vice versa [19].

The existing literature reveals that most research on the energy/electricity consumption-growth nexus fall into the omitted variable trap because they used bivariate or at most trivariate frameworks. However, this research will make use of a multivariate framework. Using a multivariate framework will avoid biased and inconsistent results caused by the omission of relevant variables [8,9]. Furthermore, most of the studies on South Africa and other countries do not examine the extent to which electricity consumption affects economic growth. Table 1 shows some selected empirical studies on the causal relationship between electricity consumption and economic growth.

3. Data and methodology

The study employs annual time series data from 1971 to 2012. The data for Gross Domestic Product (GDP) per capita, Electricity Consumption, domestic credit to private sector and CO_2 emissions were retrieved from the World Development indicators [37] of World Bank database. The data for domestic credit to private sector had a missing observation in 1991. Therefore, the linear interpolation method[1] was used to fill in the missing observation. Additionally, missing data was observed for CO_2 emissions in 2012. The data was filled by using preliminary data from CDIAC [38] for 2012 and then dividing it by total population to get a rough per capita estimate.

This study is based on the Cobb-Douglas production function. By

[1] We assume that the missing value is at time T+K and the immediate non-missing observations are at T+K-1 and T+K+J. Following the assumption, the interpolation function is expressed as; $Y(T+K) = Y(T+K-1) + (Y(T+K+1) - Y(T+K-1))/(J+I)*I$.